Astronomy®
special issue

Quick & easy: Learn the constellations

Explore the UNIVERSE®

Display until February 1, 2005

11TH EDITION 2005

Hubble • Spitzer • Chandra • Compton

NASA's greatest observatories

See the universe through their eyes

Complete guide to 2005 SKY EVENTS

Roving the Red Planet

BUYER'S GUIDE
70 go-to telescopes

Journey to a comet

The ticking bomb hidden within galaxies

A supermassive black hole surrounded by a ring of dust ejects matter at near light speed

Astronomy.com
$6.95 I $9.95 CANADA
0 09128 46770 2 55

CELESTRON®

STARHOPPER®

Celestron is proud to introduce our StarHopper series of Dobsonian telescopes available in 6", 8", 10" and 12" apertures. An excellent value for the aperture size, our StarHopper line is as rich in features as it is in value.

Features:

- Adjustable roller track bearing on the azimuth surface provides a smooth motion.
- Variable tension clutch system for proper balance and control in both altitude and azimuth.
- Optical quality BK7 annealed glass provides better thermal expansion properties than standard plate glass mirrors.
- Built-in cooling fan improves mirror cooling time and reduces damaging tube currents (for StarHopper 10" and 12" models).
- 9-point flotation mirror cell gives equal support of the primary mirror to minimize mirror deflection (for StarHopper 10" and 12" models).

Built-in cooling fan for 10″ and 12″ models

Specifications	StarHopper 6	StarHopper 8	StarHopper 10	StarHopper 12
Model Number	10600	10800	10110	10112
Primary Mirror	6″	8″	10″	12″
Focal Length	48″	48″	50″	60″
Eyepiece	25mm–1-1/4″	25mm–1-1/4″	32mm E-Lux™ 2″	32mm E-Lux™ 2″
Finderscope	6 x 30	9 x 50	9 x 50	9 x 50
Focuser	1-1/4″	2″ with 1-1/4″ adapter	2″ with 1-1/4″ adapter	2″ with 1-1/4″ adapter
Suggested Price*	**$299.00**	**$399.00**	**$549.00**	**$899.00**

* Prices shown are suggested U.S. mail order prices.

For more information about StarHopper Dobsonian telescopes and the complete selection of Celestron telescopes and accessories, binoculars, and sport optics, visit: **www.celestron.com**

2835 Columbia Street • Torrance, CA 90503 U.S.A. • Tel: 310.328.9560

LUMICON

World's Best Filters & Astronomical Accessories

Lumicon International offers you the best and most extensive line of astronomical filters in the world. Filters for every imagined visual and astrophotographic application, in many configurations and sizes. Filters for deep-sky objects, galaxies, nebulae, planets, planetary nebulae, light-polluted skies, comets, and solar prominences. All UHC, Deep Sky, Oxygen III, H-Beta and Comet Filters are individually inspected and tested on a Perkin-Elmer Double-Beam Spectrophotometer. We proudly inscribe the transmittance for each of the primary emission lines. All Lumicon filters are made to the highest standards available. Lumicon also offers a complete line of unique Astrophotographic Accessories.

Deep Sky Filters

The best light pollution filter on the market today. Blocks all high & low pressure mercury and sodium vapor lamp light, neon lights and airglow, while transmitting the rest of the visible spectrum. Excellent for both visual and photographic applications. Visually, the Deep Sky Filter is most useful under light-polluted skies, from where it reveals faint objects like star clusters, galaxies and nebulae. Photographically, the Deep Sky Filter enables deep space photos to be taken through city lights and blocks natural airglow at dark-sky sites, thus improving your results in astrophotography.

Deep Sky 1.25" and 1.25" Questar – $99.95 • 2" and 2" with T-Threads – $199.95 • Visual Back – $199.95 • 72mm – $399.95

UHC Filters

The ULTIMATE nebula filter. The original LUMICON Ultra High Contrast Filter is unbeatable for revealing nebulosity. This achievement in filter performance is attributed to exclusively designed coatings that isolate the two doubly ionized oxygen lines (496 and 501nm) and the H-beta line (486nm) emitted by planetary and most emission nebulae. The result is superb views of the Orion, Lagoon, Swan and other extended nebulae. Useful to great advantage under dark skies.

UHC 1.25" and 1.25" Questar – $99.95 • 2" – $199.95 • Visual Back – $199.95

Oxygen III Filters

The legendary LUMICON OIII narrow bandpass filter. Isolates just the two doubly ionized oxygen lines (496 and 501nm lines) emitted by diffuse, planetary and extremely faint nebulae. It produces near-photographic views of the Veil, Ring, Dumbbell and Orion nebula, among many other objects. Performs best under both light-polluted and dark skies. You will be amazed at what the OIII filter allows you to see!

Oxygen III 1.25" and 1.25" Questar – $99.95 • 2" – $199.95 • Visual Back – $199.95

H-Beta Filters

The Horsehead Nebula filter. The LUMICON H-Beta Filter isolates only the hydrogen-beta line of the spectrum (486nm). Now you can view extremely faint, special objects such as the Horsehead, Cocoon and California Nebulae. In many cases, the LUMICON H-Beta Filter is the ONLY way to view these objects. A transparent sky, with a 6" or larger instrument, used with the LUMICON H-Beta Filter, all make an unbeatable combination for viewing those "notch in the belt" objects.

Hydrogen-Beta 1.25" and 1.25" Questar – $99.95 • 2" – $199.95 • Visual Back – $199.95

Comet Filters

The LUMICON Comet Filter, a narrow visible bandpass system (25nm), isolates the 501nm OIII line and both Cyanogen lines at 511nm and 514nm. The high contrast gain of the filter reveals the delicate ionized tail of gaseous comets, allowing you to see their full extent. The Comet Filter also helps you to better distinguish gaseous comets from dusty comets which normally show little contrast gain.

Comet 1.25" and 1.25" Questar – $99.95 • 2" – $199.95 • Visual Back – $199.95

Night-Sky H-Alpha Filters

The LUMICON Night-Sky H-Alpha Filter is a powerful photographic aid in overcoming light pollution during deep-sky photography. It will help you achieve strikingly improved results in black & white film and CCD astrophotography. It is ideally matched to hypersensitized TP2415 film, and will greatly reduce light pollution, making it ideal for photography of faint emission nebulae. Exposures may be increased up to 10 times without diminishing the black background in your photograph. Both filter surfaces have high light transmittance coatings for maximum performance.

Night-Sky Hydrogen-Alpha 2" – $69.95 • 58mm – $79.95 • 77mm – $89.95 • 82mm – $99.95

Minus Violet Filters

The LUMICON Minus Violet Filter greatly improves photographs taken through lens systems, producing pinpoint star images. It is especially recommended for all telephoto lenses. The Minus Violet filter passes the maximum amount of visible light, including the full blue, green, yellow and red portions of the spectrum. It absorbs violet and ultraviolet light below 420nm, thus eliminating blue halos around bright stars in color photography. In B&W photography it eliminates bloated and swollen star images caused by violet and ultraviolet light which telephoto lenses cannot focus perfectly, due to chromatic aberration. This filter is unsurpassed in photographic performance.

Minus Violet 2" – $69.95 • 58mm – $79.95 • 72mm – $89.95

Lunar and Planetary Filters

LUMICON Lunar and Planetary filters are made from renowned Schott and Hoya optical glass. Each filter is individually precision ground and highly polished with high light transmittance coatings on both sides for ultimate contrast on Lunar and Planetary detail. Optimized for both visual and photographic applications.

#23A Light Red	#58 Green
#25 Red	#82A Light Blue
#29 Dark Red	#80A Blue
#21 Orange	#38A Dark Blue
#8 Light Yellow	#47 Violet
#12 Yellow	ND50 Neutral Density
#15 Dark Yellow	ND25 Neutral Density
#11 Yellow Green	ND13 Neutral Density
#56 Light Green	

Please visit our web site for the proper application of these filters. www.lumicon.com

All Lunar and Planetary Filters 1.25" – $19.95 • 2" – $29.95

Polarizing Filters

LUMICON Polarizing Filters are manufactured from optically flat Hoya polarized glass. They are the best for cutting all glare and increases contrast on bright celestial objects such as the moon at full illumination, and can be double-stacked with other LUMICON filters for use on bright planets. Also available in rotating polarized cell designs for variable levels of light transmittance.

Single Polarizer 1.25" – $29.95 • 2" – $39.95 • Variable Polarizer 1.25" – $39.95 • 2" – $49.95

To order please call us or visit our web site for a complete list of Lumicon authorized dealers worldwide.

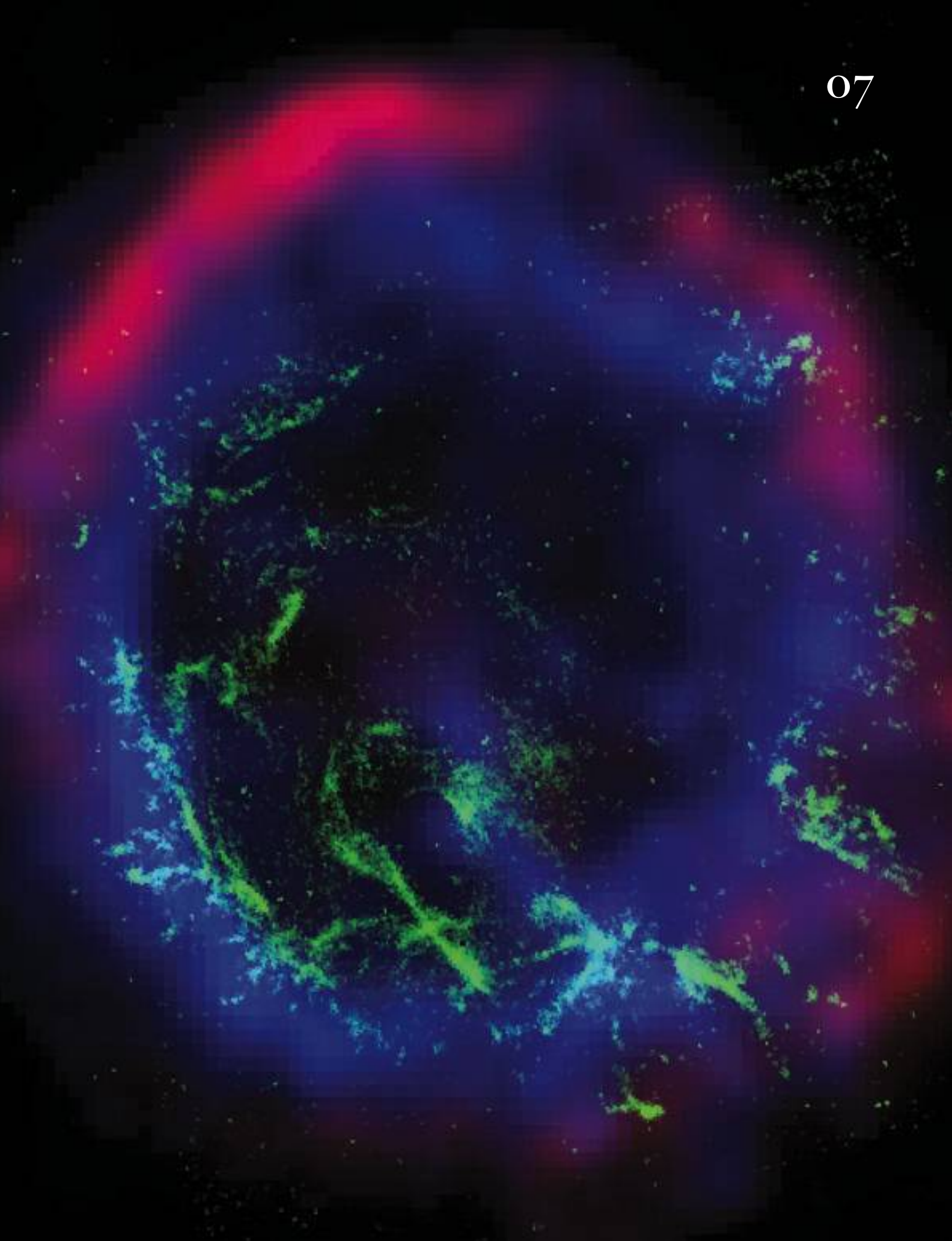
Prices do not include shipping and handling or state taxes where applicable.

LUMICON INTERNATIONAL

750 Easy Street, Simi Valley, CA 93065

805/520-0047 • Fax: 805/520-3030

www.lumicon.com



Explore the UNIVERSE 11TH EDITION — 2005

contents

EDITOR'S NOTE
06 At the eyepiece
The sizzle of astronomy

COVER STORY
07 NASA's great observatories
In just over a decade, four space telescopes have revolutionized our view of the cosmos. RICHARD TALCOTT

PLANETARY SCIENCE
18 The great Mars road trip
Two robotic geologists dropped in on Mars this past year and made historic discoveries. After exploring their landing sites, both rovers headed for more distant destinations. ROBERT BURNHAM

SPACE EXPLORATION
28 Deep Impact delivers a hit
Find out what astronomers hope to learn when a spacecraft blasts a crater into a comet. Then, set up your telescope and follow along as the comet traverses the night sky. JOHN SHIBLEY

EXTRAGALACTIC ASTRONOMY
36 A visit to the high-energy zoo
The universe is ablaze with bizarre objects spewing powerful energies into the night. Astronomers are looking to these strange creatures for insights into the universe's secrets. ROBERT ZIMMERMAN

SPECIAL SECTION
43 2005 Sky Guide
Bright planets, spectacular meteor showers, and perhaps a naked-eye comet highlight the year. Our annual guide gives you the lowdown on observing all these must-see events. MARTIN RATCLIFFE AND RICHARD TALCOTT

BASIC ASTRONOMY
68 Learn the constellations
With this roadmap to the stars, you'll have a lifetime, all-access pass to the universe — showing now, in a dark sky near you. GLENN CHAPLE

EQUIPMENT ROUNDUP
74 Your guide to go-to scopes
Today's go-to drives are extremely popular, but which scopes have them? Find out in this look at the most popular go-to telescopes. MIKE MARCOTTE

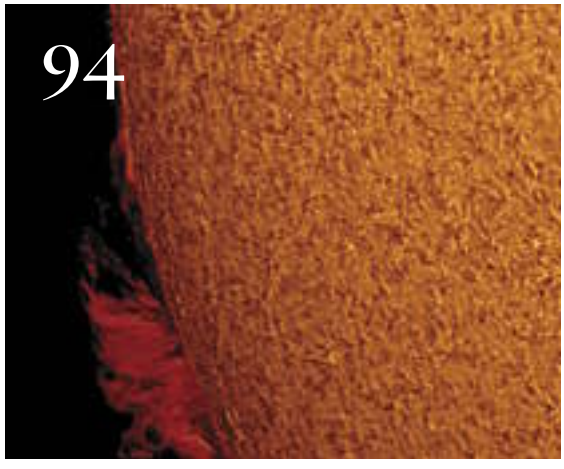
TECHNIQUES
84 The ABCs of observing
These 26 tips will help you make the most of your next observing session. MICHAEL E. BAKICH

ASTRONOMY BOOKSHELF
90 The year's best astronomy books
A rich collection of books appeared this past year on topics ranging from naked-eye skygazing to planets, cosmology, and space exploration. ROBERT BURNHAM

GREAT IMAGES
94 Venturing into the beautiful universe
Our readers have captured celestial objects near and far on film or electronic chips. *Astronomy* presents the best of these images in a tour of the cosmos.

NASA/JPL/CORNELL

ASTRONOMY: ROEN KELLY



JACK B. NEWTON

ON THE COVER
Giant black holes are among the freaks of the cosmos. Here, a supermassive black hole acts as the central engine in a galaxy, furiously blasting jets of energy outward as it devours material that cannot escape. ESA/NASA

X RAY: NASA/CXC/SAO; OPTICAL: NASA/HST; RADIO: CSIRO/ATNF/ATCA

at the eyepiece

The sizzle of astronomy

ASTRONOMY: WILLIAM ZUBACK

Everywhere you look, something big

seems to be happening in the astronomy world. Comets, transits, Mars, Saturn, digitized telescopes, and a slew of other topics made 2004 a great year for the science and the hobby of gazing at the stars. *Explore the Universe 2005* captures that spirit and reflects the diverse, amazing array of subjects now underway in research labs and soon to be appearing in every observer's backyard.

Senior editor Rich Talcott begins with a terrific article, "NASA's great observatories," on page 7, that examines the myriad contributions made by the Hubble Space Telescope, Compton Gamma-Ray Observatory, Chandra X-ray Observatory, and the newcomer, the Spitzer Space Telescope. Together, the four different wavelengths covered (visible, gamma rays, X rays, and infrared) have given astronomers, for the first time, a comprehensive view of many spectacular objects in the Milky Way and other galaxies.

Shifting from deep space to a cosmic neighbor, senior editor Robert Burnham summarizes a landmark year for Mars research in his story "The great Mars road trip," on page 18. A longtime devotee of Mars missions, Burnham provides a conclusive look back at the expeditions made by NASA's rovers Spirit and Opportunity, what they found, and what the findings will mean for future Mars landers. The story focuses on the landing sites and also the perilous journeys each lander made after touching down, seeking the most amazing areas to probe and grind. NASA's explosive discovery that many rocks were laid down in a vast amount of briny water will lead to a fuller understanding of the Red Planet's past.

Comets are becoming more than targets of amateur astronomers — they are now targets of spacecraft, too. Contributing editor John Shibley explains how Deep Impact will ram into Comet Tempel 1 July 5, 2005, in his story, "Deep Impact delivers a hit," on page 28. The unique encounter between spacecraft and comet will fire an 800-pound impactor into the comet, striking its nucleus with the incredible force of 4.8 tons of TNT.

This will create a house-size hole in the comet, spraying out gas, dust, and ice that will give astronomers their first detailed look at what's inside a comet. This, in turn, will lead to a better understanding of how the solar system formed.

Happy stargazing!

Yours truly,

Dave Eicher
Editor

Explore the Universe
11th EDITION – 2005

Editor David J. Eicher
Art Director Tom Ford

EDITORIAL STAFF
Managing Editor Dick McNally
Senior Editors Robert Burnham, Richard Talcott
Associate Editors Michael E. Bakich, Francis Reddy
Copy Editor Laura Baird
Assistant Editors Matt Quandt, Pamela Zerbinos
Editorial Associate Jeremy McGovern
Editorial Assistant Valerie Penton

CONTRIBUTING EDITORS
Bob Berman, Glenn F. Chaple, Jr., Stephen J. Edberg, Phil Harrington, David Healy, Ray Jayawardhana, Alister Ling, Steve Nadis, Tom Polakis, Martin Ratcliffe, William Schomaker, John Shibley

ART STAFF
Graphic Designer Chuck Braasch
Illustrators Kellie Jaeger, Roen Kelly, Jay Smith
Production Coordinator Joni Hauser

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, William K. Hartmann, Paul Hodge, Anne L. Kinney, Edward Kolb, Stephen P. Maran, S. Alan Stern, James Trefil

[Kalmbach Publishing Co.]
President Gerald B. Boettcher
Vice President, Editorial, Publisher James J. Slocum
Vice President, Marketing Michael R. Stephens
Vice President, Advertising Scott Stollberg
Corporate Art Director Maureen M. Schimmel
Managing Art Director Michael Soliday
Production Manager Annette Wall
Corporate Circulation Director Michael Barbee
Group Circulation Manager Michelle Spehr
Circulation Coordinators Tanya Renk, Erin Gallaher
Single Copy Sales Director Jerry Burstein

ADVERTISING DEPARTMENT
(888) 558-1544
Advertising Sales Manager Howard Hoerl
hhoerl@astronomy.com
Advertising Sales Representative Ken Kozerski
kkozerski@astronomy.com
Ad Services Representative Maria DeGrave
mdegrave@kalmbach.com

RETAIL TRADE ORDERS AND INQUIRIES
(800) 558-1544, ext. 818; outside the U.S. and Canada: (262) 796-8776, ext. 818

SPECIAL E-MAIL ADDRESSES
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Customer Service customerservice@kalmbach.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader gallery readergallery@astronomy.com

Explore the Universe 2005 (ISSN 1089–4926) is published annually by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187–1612. *Astronomy* editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service and subscriptions: (800) 533-6644, 7 days a week, 24 hours a day; fax: (262) 796-1615. SINGLE COPY PRICE: U.S. $6.95, Canada $9.95, and U.K. £2.95. Canadian price includes GST. BN 12271 3209 RT. Canadian and international orders payable in U.S. funds. POSTMASTER: Send address changes to: *Explore the Universe 2004*, Kalmbach Publishing Co., 21027 Crossroads Circle, Waukesha, WI 53187–1612.

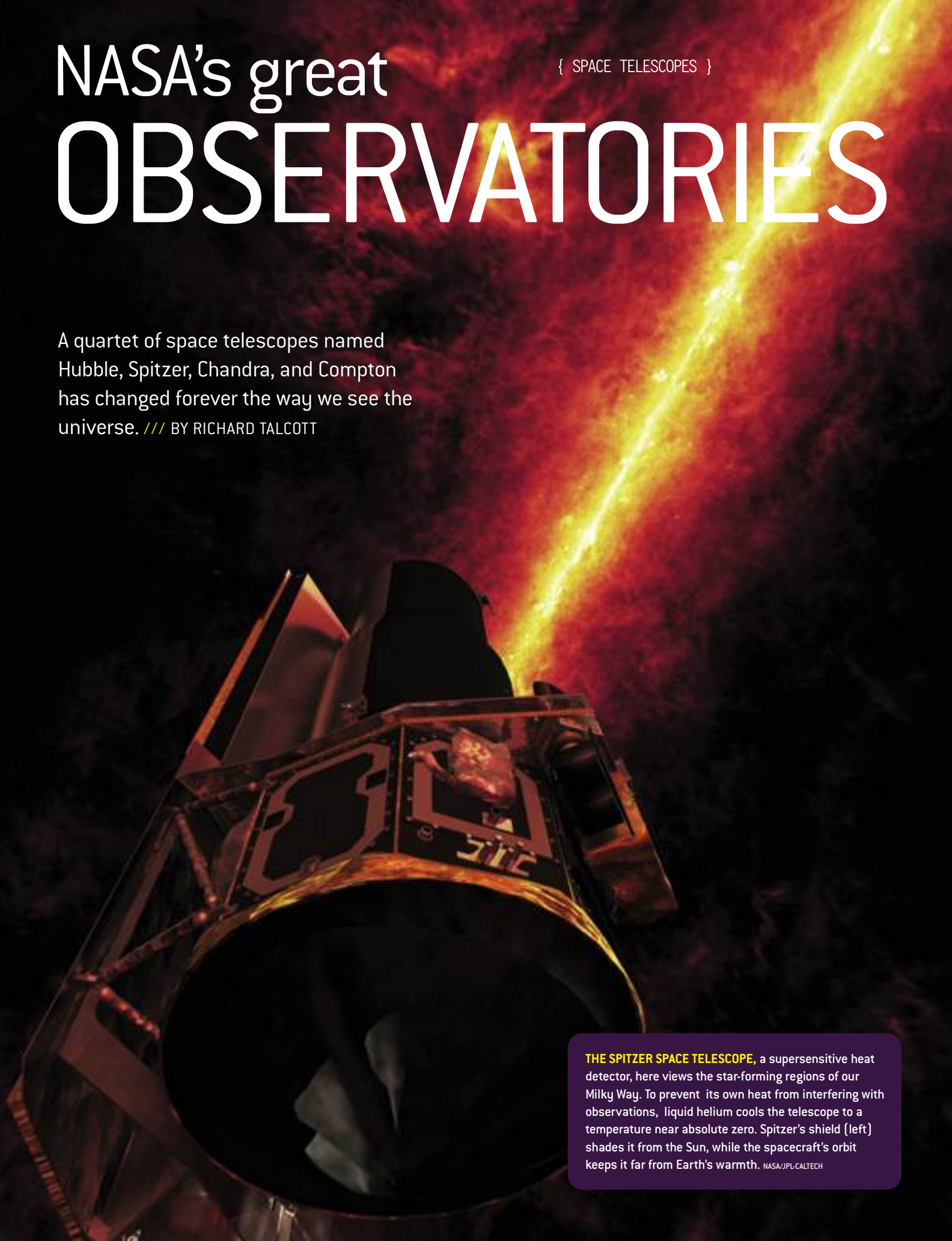
Copyright © 2004 Kalmbach Publishing Co. Title registered as trademark; all rights reserved. Material in this publication may not be reproduced in any form without permission.

Standard class postage paid at Waukesha, WI, and additional offices. Printed in the U.S.A.

For more information visit:
www.astronomy.com

NASA's great OBSERVATORIES

A quartet of space telescopes named Hubble, Spitzer, Chandra, and Compton has changed forever the way we see the universe. /// BY RICHARD TALCOTT



THE SPITZER SPACE TELESCOPE, a supersensitive heat detector, here views the star-forming regions of our Milky Way. To prevent its own heat from interfering with observations, liquid helium cools the telescope to a temperature near absolute zero. Spitzer's shield (left) shades it from the Sun, while the spacecraft's orbit keeps it far from Earth's warmth. NASA/JPL-CALTECH

MOST OF US ARE QUITE FOND OF THE blanket of air that surrounds Earth. After all, its oxygen keeps us alive while ozone and other molecules protect us from the ravages of high-energy radiation. But astronomers are a funny lot. As much as they appreciate the atmosphere's life-sustaining benefits, they curse its effect on their ability to view the universe.

Inevitably, even on a crystal-clear night, visible light streaming through the atmosphere encounters pockets of warm and cool air and becomes distorted. This causes stars to twinkle — and prevents astronomers from obtaining sharp views. Just as annoying, the atmosphere completely prevents cosmic gamma rays and X rays from reaching Earth's surface and blocks most of the incoming ultraviolet and infrared radiation.

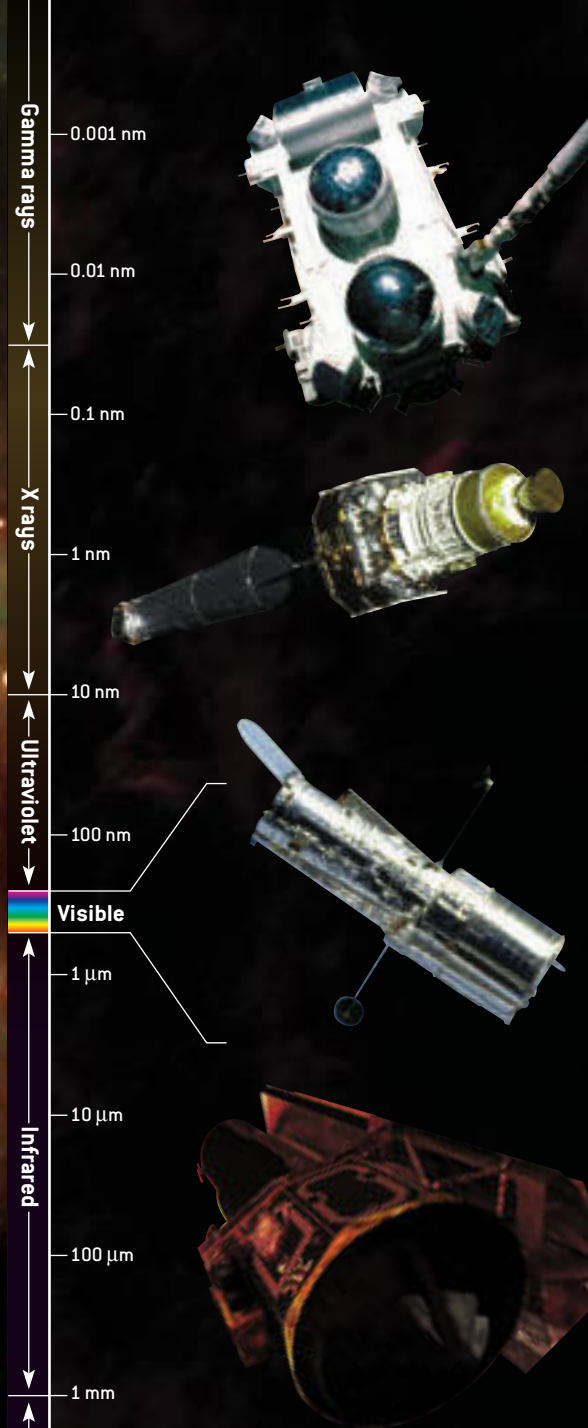
That's why NASA decided to embark on its Great Observatories program. The program envisioned lofting four observatories, each optimized for viewing a different part of the electromagnetic spectrum, well above the atmosphere's harmful effects. The images on these pages represent a tiny fraction of what these observatories have achieved so far, and they only hint at what they may accomplish in the future.

The Hubble Space Telescope was the first of the Great Observatories to reach space. Deployed from the space shuttle Columbia in April 1990, Hubble orbits Earth at an altitude of approximately 370 miles (595 kilometers). Its instruments explore the universe at wavelengths ranging from ultraviolet through visible light and into the near infrared.

Richard Talcott *is a senior editor of* Astronomy.

THE TARANTULA NEBULA in the Large Magellanic Cloud marks the site of the largest region of star formation in the nearby universe. This Hubble visible-light mosaic probes the swirls of gas and dust around the nebula's central star cluster, R136. The cluster is so dense it was once thought to be a single star. NASA, J. TRAUGER (JPL), J. WESTPHAL (CALTECH), N. WALBORN (STScI), AND R. BARBÁ (LA PLATA OBSERVATORY)

WITH SPITZER'S INFRARED EYES, the Tarantula Nebula resolves into spidery filaments and newborn stars. Spitzer shows a much wider field of view than Hubble; the massive R136 star cluster lies within the brightest region. The energetic light from massive stars sets the nebula aglow. Violent stellar winds sculpt the gas into filaments. NASA/JPL-CALTECH/B. BRANDL (CORNELL AND UNIVERSITY OF LEIDEN)



NASA'S FOUR GREAT OBSERVATORIES allow unprecedented views of the universe at four different wavelengths. Until its demise in June 2000, Compton observed ultra-high-energy gamma rays. The other three spacecraft continue to operate: Chandra at X-ray wavelengths, Hubble in visible light, and Spitzer in infrared. Hubble, the first launched of the series, had a rocky start thanks to a flawed primary mirror, but it has been working perfectly since February 1997. Together, the Great Observatories provide an unprecedented view of the cosmos.

ASTRONOMY: ROEN KELLY

Although Hubble began its career with great expectations, those came crashing down when initial images revealed a flaw in the main mirror — Hubble couldn't focus light sharply. Fortunately, NASA designed Hubble to be serviced regularly. In December 1993, astronauts on the shuttle Endeavour fit Hubble with high-tech "glasses," which completely corrected its fuzzy vision. In the decade since, Hubble has delivered on its initial promise — and then some. But the servicing missions didn't stop in 1993. Three more shuttle visits have seen astronauts replace all of the telescope's original instruments, helping to keep it at the forefront of technological innovation and astronomical discovery.

Since December 1993, Hubble has observed objects as close as Earth's Moon and as far as the most distant galaxies ever seen. It serves as a planetary weather satellite, allowing astronomers to track changes in the atmospheres of the outer planets. It witnessed the explosive impacts of comet fragments when Shoemaker-Levy 9 crashed into Jupiter in 1994. Hubble's observations of newly forming stars showed that disks of gas and dust — the stuff from which planets form — are common around young stars and contain enough mass to form entire planetary systems.

But perhaps Hubble's biggest accomplishments have been its observations of objects beyond our own Milky Way Galaxy. It pinned down the expansion rate and distance scale of the universe by resolving and tracking the changing light output of Cepheid variable stars nearly 100 million light-years from Earth. It provided the first proof that black holes exist by showing

THE TATTERED REMAINS of a massive star spread outward into the Large Magellanic Cloud. Dubbed N49, this supernova remnant consists of heavy elements forged inside a star that exploded thousands of years ago. Someday this material will be incorporated into new generations of stars — and possibly planets. NASA AND THE HUBBLE HERITAGE TEAM (AURA/STScI)

GRACEFUL SPIRAL ARMS wind their way out from the nucleus of M81, a nearby galaxy in Ursa Major. Warm dust dominates the spiral arms, making them the galaxy's most prominent feature at the long wavelengths mapped by Spitzer. Knots of emission highlight dense hydrogen clouds, regions where active star formation is taking place. NASA/JPL-CALTECH/S. WILLNER (CfA)

THE HELIX NEBULA gives us a glimpse at what the future holds for stars like our Sun. The nebula's central star has ejected its outer layers. Radiation from the bare stellar core sets the gas aglow. Astronomers still aren't sure what causes the peculiar knots on the nebula's inner edge. This image is a composite of Hubble and ground-based images. NASA/WIYN/NOAN/ESA/M. MEIXNER (STScI), AND T. A. RECTOR (NRAO)

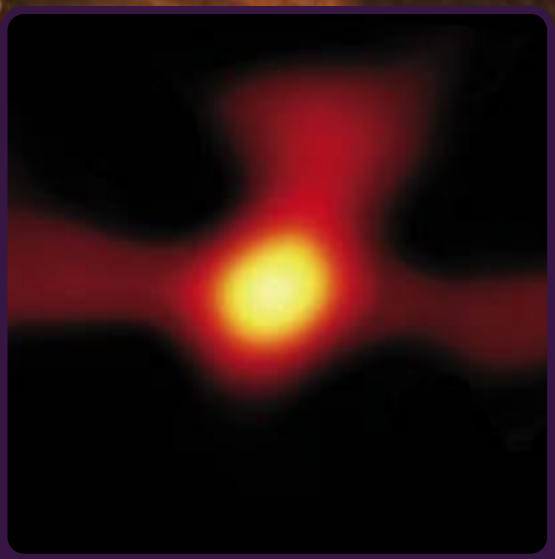
that dark objects with masses more than a billion times the Sun's mass lurk in the centers of galaxies. And it showed that each of those supermassive black holes has a mass equal to about 0.2 percent of its entire galaxy's mass. It helped prove that quasars are the energetic centers of distant galaxies, many of which appear to be interacting with other galaxies. And in a recent image dubbed the Hubble Ultra Deep Field, it captured faint, reddish galaxies that formed within about 400 million years of the Big Bang, making them the youngest galaxies ever seen.

At the top of Hubble's list of achievements is its study of exploding stars, or supernovae, in the distant universe. Observations show these supernovae are moving away from us faster than can be explained by the force of gravity alone. The only explanation: Some mysterious force, dubbed "dark energy" by astronomers, is causing the universe to expand at an accelerating pace.

NASA's second Great Observatory rode into space on the shuttle Atlantis in 1991. The Compton Gamma Ray Observatory probed gamma rays, the most energetic form of radiation in the universe, from its perch 280 miles (450 km) above Earth's surface. At 17 tons, Compton ranks among the heaviest astronomical payloads ever lifted into space. That weight ultimately led to its demise. NASA decided that the observatory would pose a slight but real risk of crashing back to Earth if a second gyroscope failed. The space agency brought Compton down in June 2000, and it burned up over the Pacific Ocean.

During its nine years in space — nearly twice its intended five-year life span — it discovered ten times more gamma-ray sources than previously

X RAYS FROM 47 TUCANAE indicate that even old stellar systems have pockets of heated activity. Nearly all the objects in this Chandra image represent binary systems where a normal Sun-like star is dumping material onto a collapsed object, either a white dwarf or neutron star. Chandra found ten times the number of X-ray sources here than previous X-ray satellites. NASA/CfA/J. GRINDLAY ET AL.



AN ANTIMATTER FOUNTAIN spurts upward 3,000 light-years from the plane of our galaxy in this gamma-ray view taken by Compton's OSSE instrument. When positrons (antimatter electrons) collide with normal electrons, they are annihilated in a burst of gamma-rays. The source of the positrons remains a mystery.
D. D. DIXON (UNIV. OF CALIFORNIA, RIVERSIDE) AND W. R. PURCELL (NORTHWESTERN UNIV.)

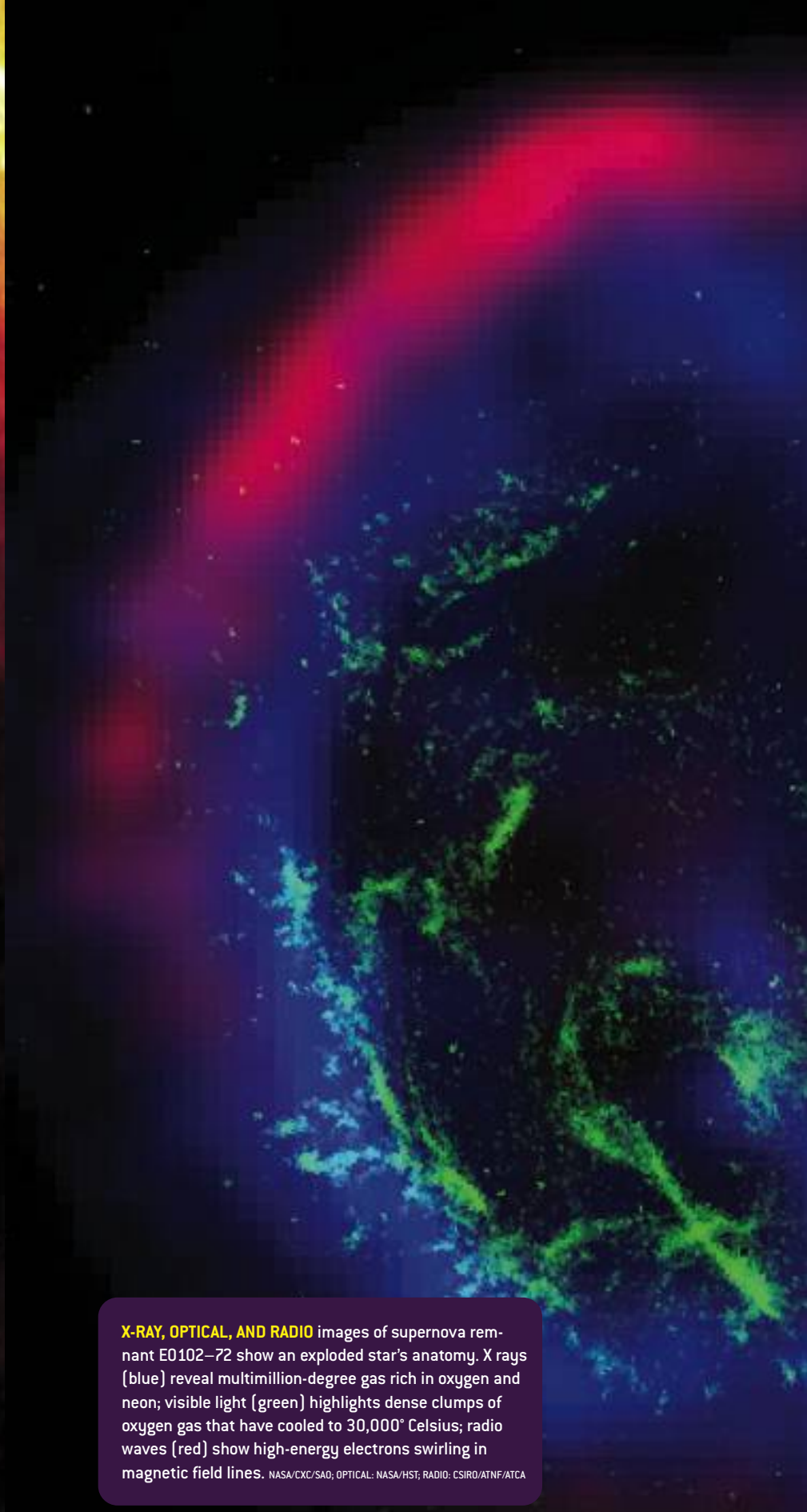
THE BUG NEBULA flares out from a hot, young star embedded in a thick torus of dust. The dusty disk hides the star from direct view, but Hubble captured its effects on the fan-shaped nebula. Energized by the star's intense ultraviolet light and its strong stellar wind, the gas escapes in the only direction it can — perpendicular to the disk, along its axis of spin. NASA/ESA/A. ZIJLSTRA (UMIST)

known, an antimatter fountain erupting in the center of our galaxy, and jets of matter streaming away from black holes at nearly the speed of light.

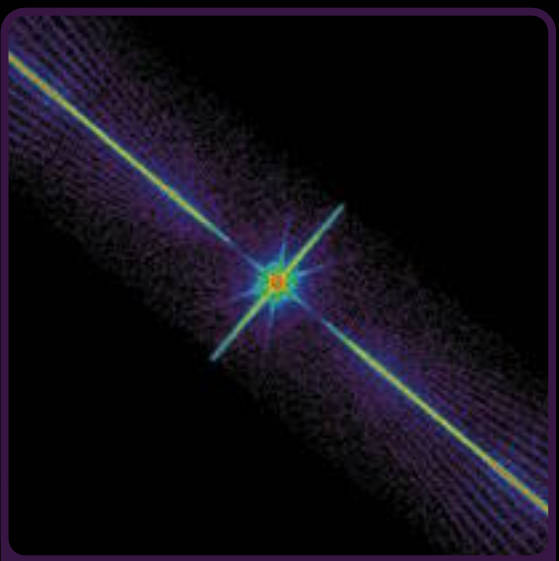
But it will be remembered most for proving that gamma-ray bursts are the most powerful explosions in the universe. Before Compton's launch, most astronomers suspected these intense, short-lived bursts originated in the disk of our own galaxy. But Compton showed they appeared from every direction and, therefore, must originate in the distant universe. (Hubble later observed the fading afterglow from some of these bursts, proving they erupt in faint, remote galaxies.)

More than eight years elapsed before the third Great Observatory reached orbit. The Chandra X-ray Observatory rode into space aboard the shuttle Columbia in July 1999. A built-in propulsion system then boosted the observatory into a highly eccentric orbit around Earth. It comes within 10,000 miles (16,100 km) of the surface at its closest approach but swings out to a maximum distance of nearly 83,000 miles (133,600 km) — more than a third of the way to the Moon. The unusual orbit was designed so that Chandra spends about 85 percent of its time above the Van Allen radiation belts, where charged particles would overwhelm the observatory's sensitive instruments. This allows astronomers to observe uninterrupted for as long as 55 hours at a stretch.

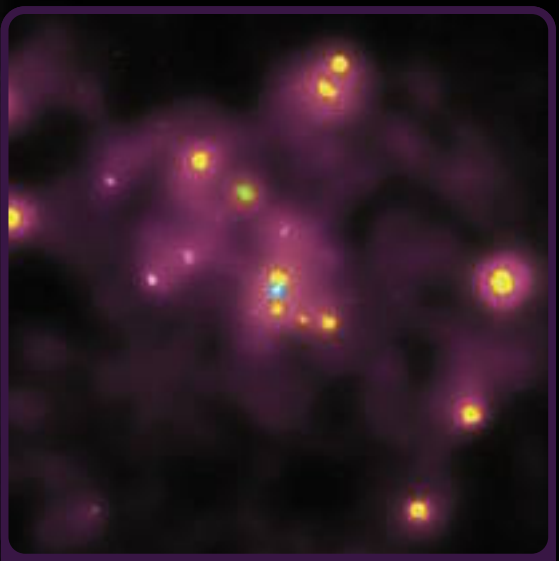
Chandra observes X rays, radiation with energies and wavelengths between those of gamma rays and ultraviolet radiation. Chandra spends its time observing high-energy events in black holes, pulsars, supernova remnants, and the cores of galaxies. It has seen



X-RAY, OPTICAL, AND RADIO images of supernova remnant E0102–72 show an exploded star's anatomy. X rays (blue) reveal multimillion-degree gas rich in oxygen and neon; visible light (green) highlights dense clumps of oxygen gas that have cooled to 30,000° Celsius; radio waves (red) show high-energy electrons swirling in magnetic field lines. NASA/CXC/SAO; OPTICAL: NASA/HST; RADIO: CSIRO/ATNF/ATCA



THE BLACK HOLE BINARY SYSTEM XTE J1118+480 consists of a Sun-like star in orbit around a black hole. This Chandra spectrum (the long, bright line) shows that the disk of incoming material drawn from the companion comes no closer than 600 miles (970 km) to the black hole. The gas may erupt into a hot bubble before it can fall any farther. NASA/CfA/J. McCLINTOCK AND M. GARCIA



THE ANDROMEDA GALAXY'S CORE resolves into a multitude of X-ray sources in this detailed Chandra image. A supermassive black hole with an estimated mass of 30 million suns lurks at the very center. It resides inside the bright yellow blob just above the cool X-ray source shown in blue. About 10 light-years separate these two sources. NASA/SAO/CXC/M. GARCIA ET AL.

radiation released by the supermassive black hole at the Milky Way's center as it devours surrounding material. Its observations of the bright galaxy NGC 6240 in Ophiuchus proved that two supermassive black holes can coexist in the same galaxy. Sometime within the next billion years, these two will merge in a catastrophic event that will create an even bigger black hole. And Chandra has watched high-energy jets from black holes and pulsars evolve in strange and unanticipated ways.

The latest addition to the Great Observatories program is also its last — the Spitzer Space Telescope, which was launched in August 2003 on an expendable rocket. It observes infrared radiation, with wavelengths longer than visible light, emanating from cool regions of space. It is the only one of the Great Observatories not in orbit around Earth. Instead, NASA placed it in orbit around the Sun, where it trails Earth and drifts slowly away from its home planet. This orbit keeps the telescope much cooler than it would be if it orbited a warm Earth, reducing the amount of coolant needed to keep the detectors cold.

Because infrared light can penetrate dusty environments, Spitzer will produce detailed images of star- and planet-forming regions hidden from view at other wavelengths. It also will be able to observe remote galaxies whose visible light has been shifted into the infrared by the expansion of the universe. Although it has only recently started observing the universe, Spitzer is a vital component of the Great Observatories program, a program that will continue to amaze astronomers and the public alike for years to come.

SCULPTED BY FIERCE WINDS and ionizing radiation from a massive star off the left edge of this Spitzer image, a cloud of gas and dust glows brightly in infrared light. The stellar nursery, which looks like a dark globule in visible-light images, belongs to emission nebula IC 1396 in Cepheus. Spitzer found a half dozen new protostars within the globule. NASA/JPL-CALTECH/W. REACH (SSC/CALTECH)

THE PENCIL NEBULA (NGC 2736) forms a tiny part of the vast Vela supernova remnant. The explosion's shock wave swept up interstellar gas and heated it to millions of degrees. Over millennia, the gas cooled into the filaments we see today. The Pencil Nebula measures three-quarters of a light-year across; the entire Vela remnant spans 114 light-years. NASA AND THE HUBBLE HERITAGE TEAM (AURA/STScI)

THE LINDSAY-SHAPELY RING GALAXY resembles a diamond bracelet. Bright, blue star clusters gleam along its rim, a clue that a massive burst of star formation has occurred in the galaxy's recent past. Eons ago, another galaxy plunged straight through its disk, an event that both fueled the starburst and distorted the galaxy into its circular shape. NASA/ESA, AND THE HUBBLE HERITAGE TEAM

The great Ma

In early 2004, NASA landed two rovers on Mars to locate sites where water has been abundant.

"THIS IS THE MOST SPECTACULAR VIEW WE'VE SEEN ON THE MARTIAN SURFACE," said rover chief scientist Steve Squyres of Cornell University. When he spoke, one of NASA's two Mars Exploration Rovers (MERs) had just rolled up to the lip of a big crater dubbed Endurance. Both rovers are now seeking new targets in an extended mission that promises to last into the martian winter and perhaps beyond. Spirit is in the Columbia Hills, more than 2 miles from its landing site, and Opportunity is prowling the rocks inside Endurance, examining outcrops that reveal new chapters in the planet's sedimentary past. Designed to last only 90 martian days, or about 3 Earth months, the rovers have greatly exceeded their initial missions in duration, geographic range, and quality of discovery.

Mars is no simple place; it has a geological history tangled far beyond the ability of any single mission — or even dozens of them — to unravel in detail. Yet while underscoring the planet's complexity, the remarkable explorations of Opportunity and Spirit have cracked open a door into the martian past.

MAZATZAL ROCK lies on the rim of Bonneville Crater. This lava rock, sculpted by wind-blown dust, has mineral deposits in cracks that suggest small amounts of water altered it.

ars road trip

What they found surpassed all expectations. /// BY ROBERT BURNHAM

SPIRIT'S WHEELS (left) make useful digging tools, as seen in its work on a small drift of sand nicknamed Serpent. In the background lies Bonneville Crater, seen more clearly below. **ELSEWHERE ON THE RIM** of Bonneville (center), blocks of ejecta mingle with blown sand and dust to make a scene familiar to anyone who has explored the desert Southwest of the United States. **LOOKING LIKE A TRUSSED TURKEY,** (right) this rock is a piece of the lava flows that filled Gusev; it was excavated by a meteorite impact, then weathered. The holes at one end suggest the lava contained a lot of gas when it erupted.

BONNEVILLE CRATER is about 660 feet across and 60 feet deep. It lies about 1,000 feet from Spirit's landing site in Gusev Crater. Scientists hoped that Bonneville would harbor lakebed deposits in its interior. But while Spirit found individual rocks showing effects from water, the rocks themselves all proved volcanic — pieces of lava. ALL PHOTOS: NASA/JPL

NASA's plans for exploring Mars center on a search for water, either where it may be now or where it was in former times. Water seems essential to life, and scientists feel our best chance for finding an extraterrestrial biology starts with "following the water."

The two MERs were sent specifically to locate prime sites that could be revisited with the intent of bringing back samples. These might, if we are extraordinarily lucky, contain traces of life, either current or former. Even if the samples prove barren, they will advance our understanding of Mars.

Crater lake?

Both rovers landed in January 2004: Spirit inside a 100-mile-diameter crater named Gusev, and Opportunity on an Oklahoma-size plain called Meridiani Planum. Scientists chose Gusev because orbital surveys suggested it once contained a lake. Meridiani caught their attention when remote sensing showed lots of hematite, an iron mineral associated with water. (See *Astronomy*, April and May 2004.)

Spirit landed first, on January 2. Its initial panoramic images showed the best scenery of any Mars surface photos yet taken. A low, undulating range, soon named the Columbia Hills (to honor the fallen shuttle astronauts), forms the southeastern skyline.

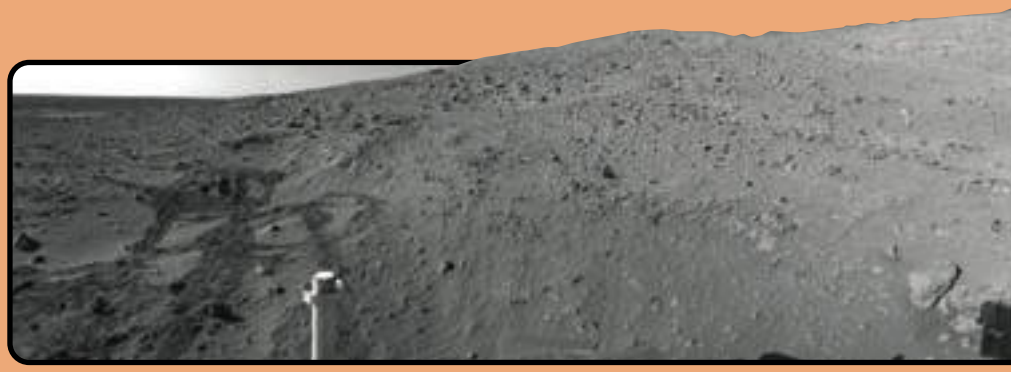
But as Spirit explored the area around its landing site, including a nearby crater named Bonneville, its instruments detected little in the rocks and soil resembling lakebed deposits. The rocks are basalt, a common volcanic rock found on all terrestrial planets. A number of rocks Spirit examined show water's effects — mineral deposits in cracks, weathering rinds — but the amount of water appears minor, perhaps little more than what repeated coatings of frost could accomplish. Moreover, the dusty soil holds olivine, a mineral that decomposes quickly on exposure to water. These findings imply that Gusev's surface hasn't seen an ocean or lake in a very long time.

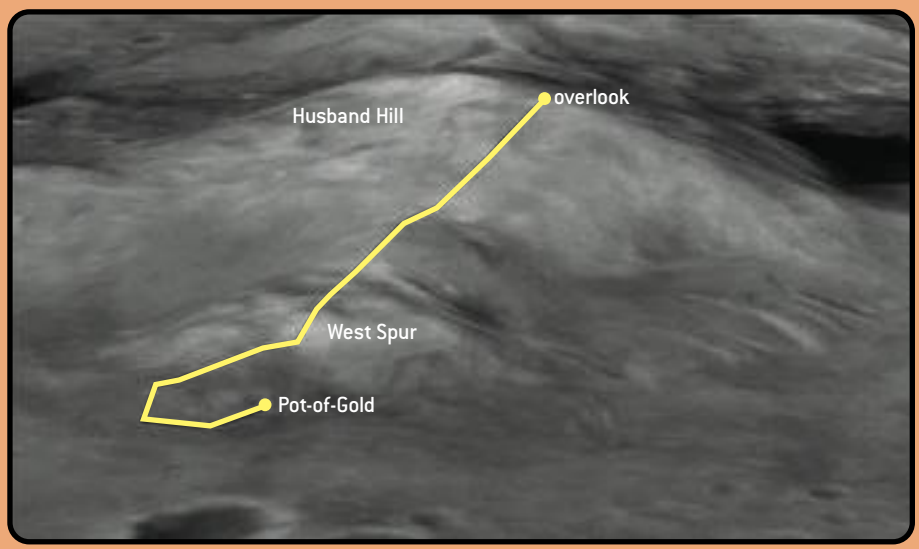
Scientists turned their attention to the Columbia Hills, hypothesizing that these are upthrust sections of earlier deposits within Gusev — relics, perhaps, of an era when water may have been more prevalent.

Into the hills

Spirit reached the foot of the Columbia Hills in June, six months after landing. Immediately,

Robert Burnham *is a senior editor of* Astronomy.

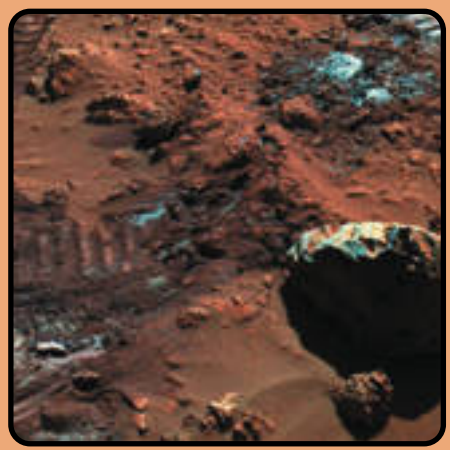




UP AND OVER THE HILL is the route for Spirit. After examining rocks and outcrops at Pot-of-Gold, the rover will make its way to where the slope of West Spur is gentle enough to climb. Spirit will visit numerous outcrops on its way to an overlook on Husband Hill that has a view into a basin beyond.

TRENCHING AT THE FOOT OF THE HILLS revealed magnesium sulfate in the soil. The mineral probably was deposited by small amounts of acidic water percolating through the ground and evaporating.

LOOKING UP WEST SPUR, Spirit's navigation camera catches boulders, outcrops, and rocky debris on the slope of the Columbia Hills. Scientists expect the hills to contain rocks older than the lava flows that make up the present floor of Gusev Crater — and they hope to find signs of water-deposited materials.



A ROCK CALLED POT-OF-GOLD (left) casts a tattered-looking shadow, thoroughly puzzling scientists because it resembles nothing seen before on Earth or Mars. **VIEWED AT CLOSE RANGE** with Spirit's microscopic imager (center), Pot-of-Gold shows a deeply eroded surface with nodules perched on stalks; the nodules' origin remains unknown. **IN HANK'S HOLLOW,** an area containing Pot-of-Gold and other unusual rocks (right), Spirit's wheels disturbed the soil, giving it a bright, sparkly, dust-like appearance when seen in false color. Mission scientists are not sure what produces this effect.

FROM HALF A MILE AWAY, the Columbia Hills beckon to Spirit. The highest is Husband Hill, which rises some 300 feet above the plain.

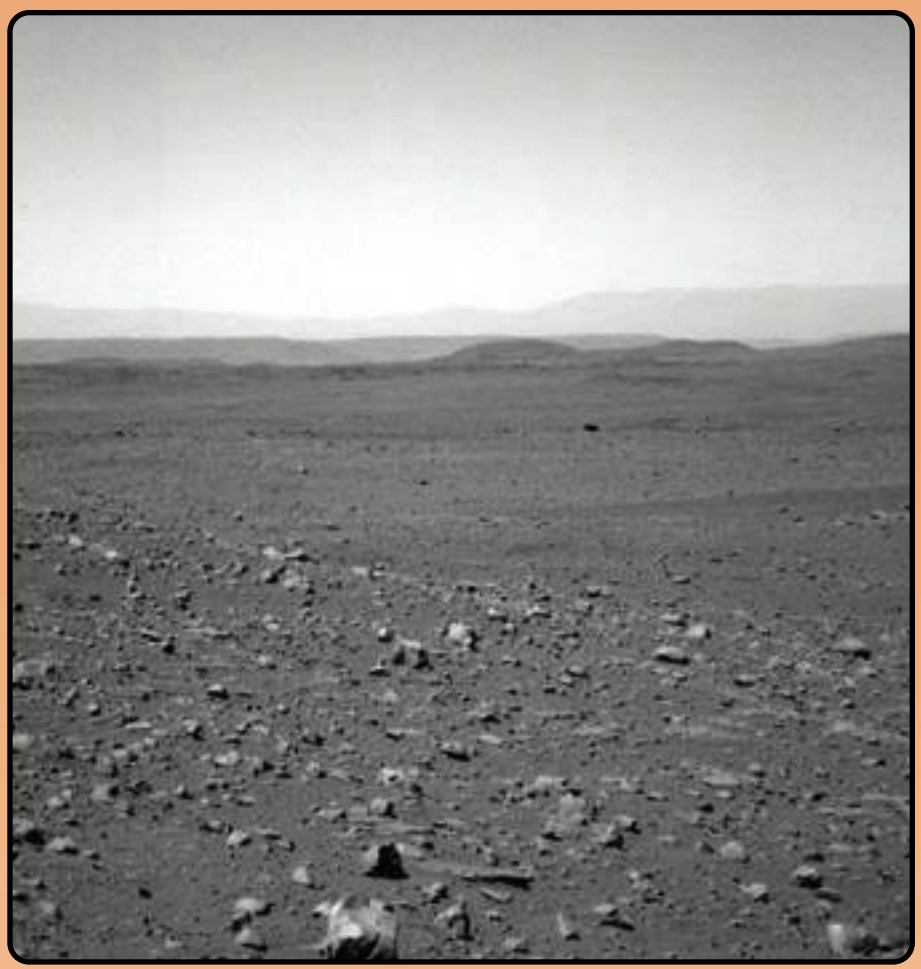
the rover found rocks and soil that may have been altered by moderate amounts of water. A trench dug in the soil revealed magnesium sulfate. This was produced, scientists say, as small amounts of acidic water percolated through the soil, dissolving minerals in rock particles. When the water evaporated, it left magnesium sulfate near the surface.

One rock, dubbed Pot-of-Gold, contains nodules that initially appeared like the hematite-rich spheres found in great abundance by Opportunity in Meridiani. Yet Spirit's instruments revealed that, while Pot-of-Gold contains hematite, it is not in the nodules. Scientists are trying to determine the hematite's origin.

More startling, however, were the close-up images of Pot-of-Gold and its nodules taken with the rover's microscopic imager. They show the rock is unlike anything yet seen on Mars — or Earth. "I don't know *how* these nuggets formed," said Squyres, "and it's driving me nuts!"

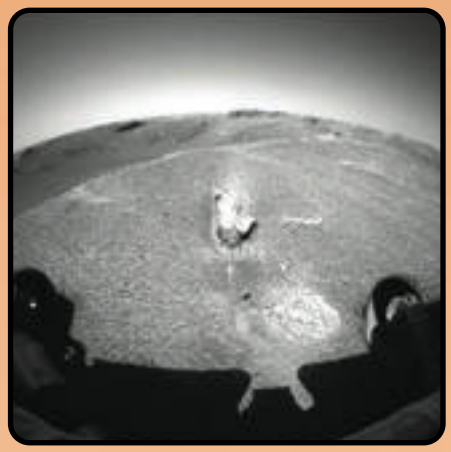
Scientists plan to explore Pot-of-Gold's vicinity before driving Spirit up a low ridge called West Spur. The drive will take it to an overlook above an inner basin, where orbital photos show more rock layers are exposed.

As autumn begins in Earth's Northern Hemisphere, Spirit is descending into martian winter. On September 15, Mars passes on the far side of the Sun, making communications patchy. Before then, mission controllers will find a site where Spirit can safely winter over, parking it on a slope where its solar panels can catch as many Sun rays as possible. Assuming



DISTANT RIDGES FADE INTO HAZE in an image Spirit made from the lowest slopes of the hills. The view is toward the south, and the rim of Gusev Crater forms the farthest ridgeline. Next closest are the southern mesas, perhaps remnants of debris washed down from Ma'adim Vallis into Gusev.

OPPORTUNITY VISITED THE ANATOLIA FRACTURES briefly on the drive to Endurance Crater. These linear features have an unknown origin, but the light-colored rock just below the surface is the soft, sulfate-rich evaporite layer first seen in Eagle Crater. Note how flat Meridiani Planum is compared to Gusev.



DIMPLES AND DUNES (left) mark the surface of Meridiani. Dark hematite-bearing "blueberries" that eroded out of the sulfate layer densely cover the ground as wind-blown sand forms tiny ridges and streaks. Endurance stands in the background at left. **LION ROCK** (center) is a piece of debris lying on the rim of Endurance; examination with Opportunity's instruments showed it is part of the Eagle Crater sulfate layer. **WAVY LINES POINT** (right) to a maritime birth for the sediments making up this rock at Endurance. Details of the rock's layers show that they were laid down in shallow water, and their sulfate geochemistry tells scientists the water was acidic and salty.

HUSBAND HILL STANDS AT LEFT with West Spur being a low, descending ridge in the center of the frame. Spirit will drive up the Spur and look over the hill.

nothing breaks, Spirit will resume its exploring as martian winter turns to spring.

To the shores of Meridiani

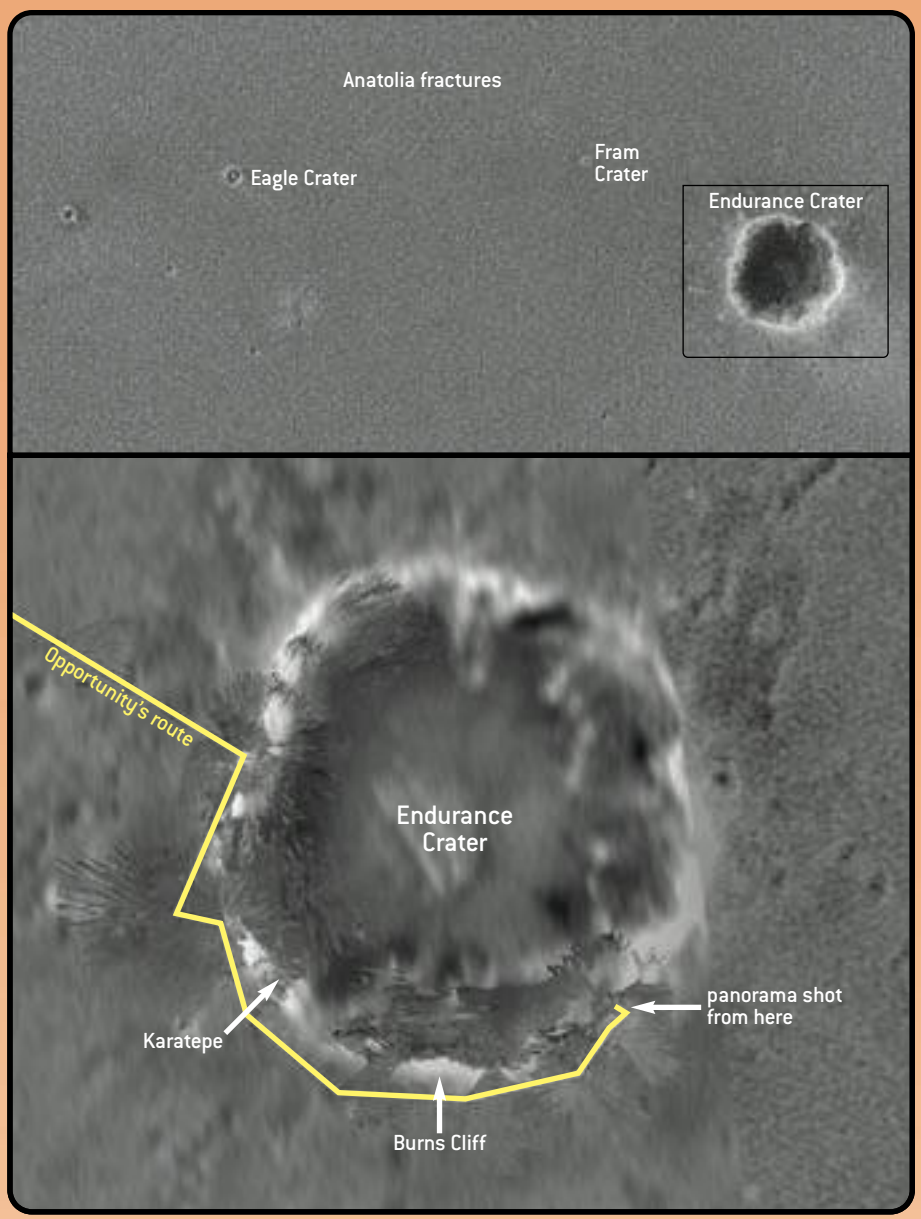
A different geological story greeted Opportunity on the other side of Mars. Bouncing to a halt on January 25 inside Eagle Crater, which is about 70 feet across and 6 feet deep, Opportunity opened its imager "eyes" and saw a long outcrop of whitish rock about 25 feet away.

Analysis of the outcrop during the rover's 2-month stay in Eagle shows several things: the rock is sedimentary; it was laid down in water; it contains internal structures (cross-bedding) that show the water was shallow; and it is rich in salts and sulfate evaporite minerals. They indicate the outcrop rock is the dried residue of a salty, acidic sea. This was fantastic news for scientists — and exactly what the rovers had been sent to find.

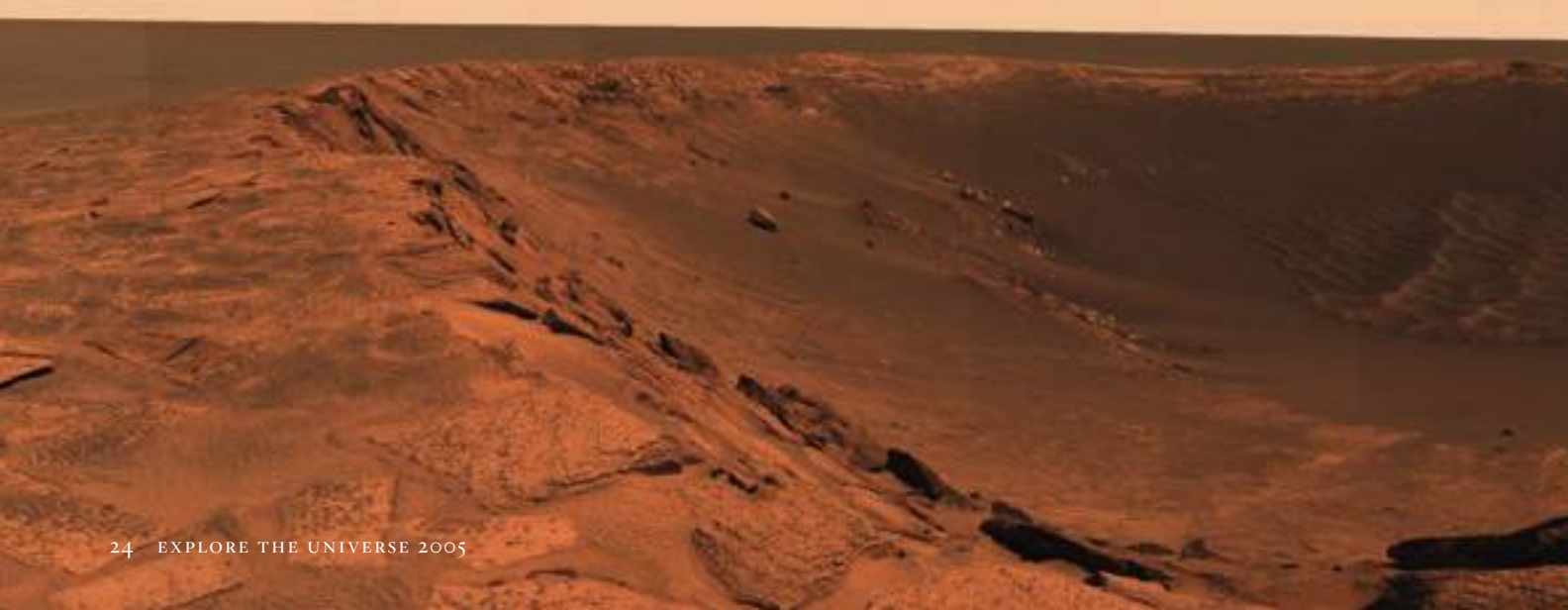
Opportunity also found the source of the hematite seen from orbit. It consists of spherules about the size of BBs that scientists were soon calling "blueberries." They are strewn everywhere on the Meridiani plains, except where buried by the sand and dust that accumulate in the bottom of craters like Eagle. Geologists say the blueberries are concretions that formed around chemical impurities within the evaporite layer when it was drenched in water. Being tougher than the deposit itself, the berries weathered out as the evaporite layer eroded, leaving them as a lag deposit.

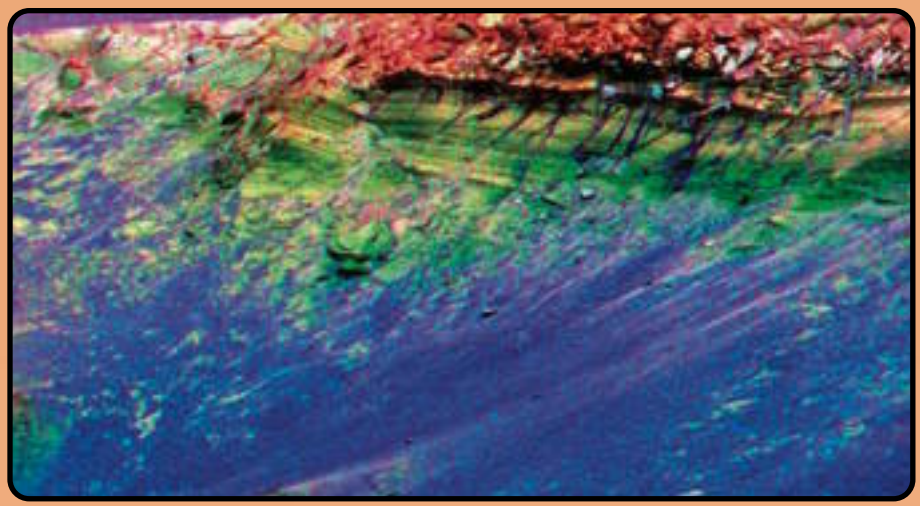
Reading earlier chapters

When Opportunity left Eagle's vicinity, it drove half a mile east to Endurance Crater (see below). Endurance's depth gave access to a longer sequence of sedimentary layers than in Eagle. In fact, most of the layers exposed in Endurance lie stratigraphically lower (which

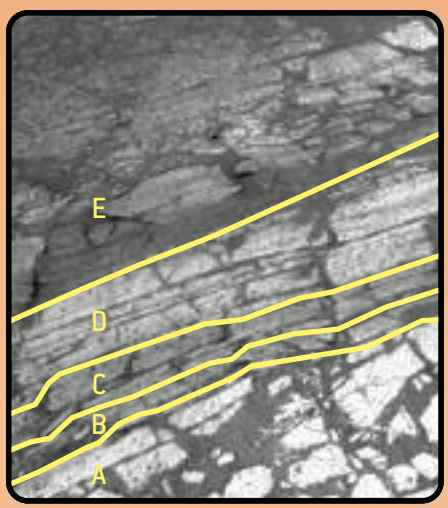


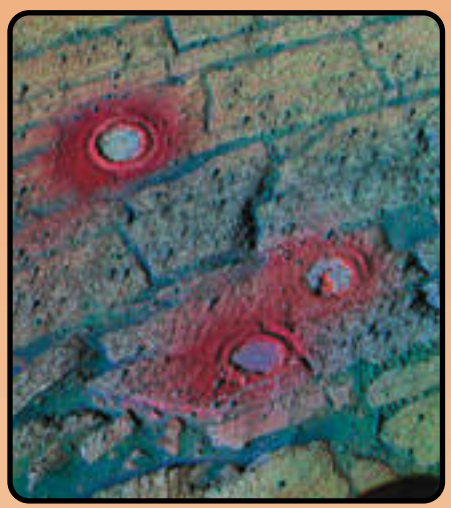
OPPORTUNITY MADE A HOLE-IN-ONE (top) by landing inside tiny Eagle Crater. On leaving Eagle, the rover visited Anatolia and Fram Crater before going to Endurance Crater, seen above in a composite of images taken from orbit and on the ground. Deposits in Endurance have opened up the martian past.

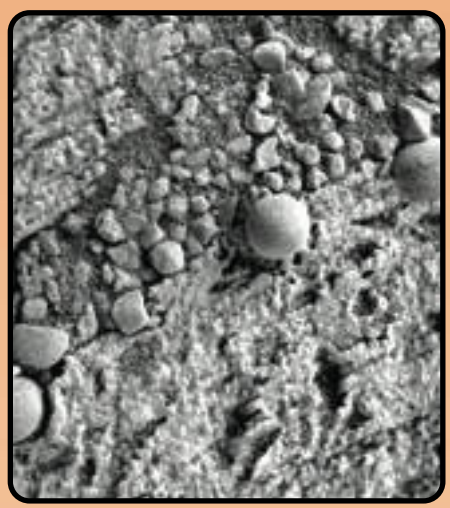




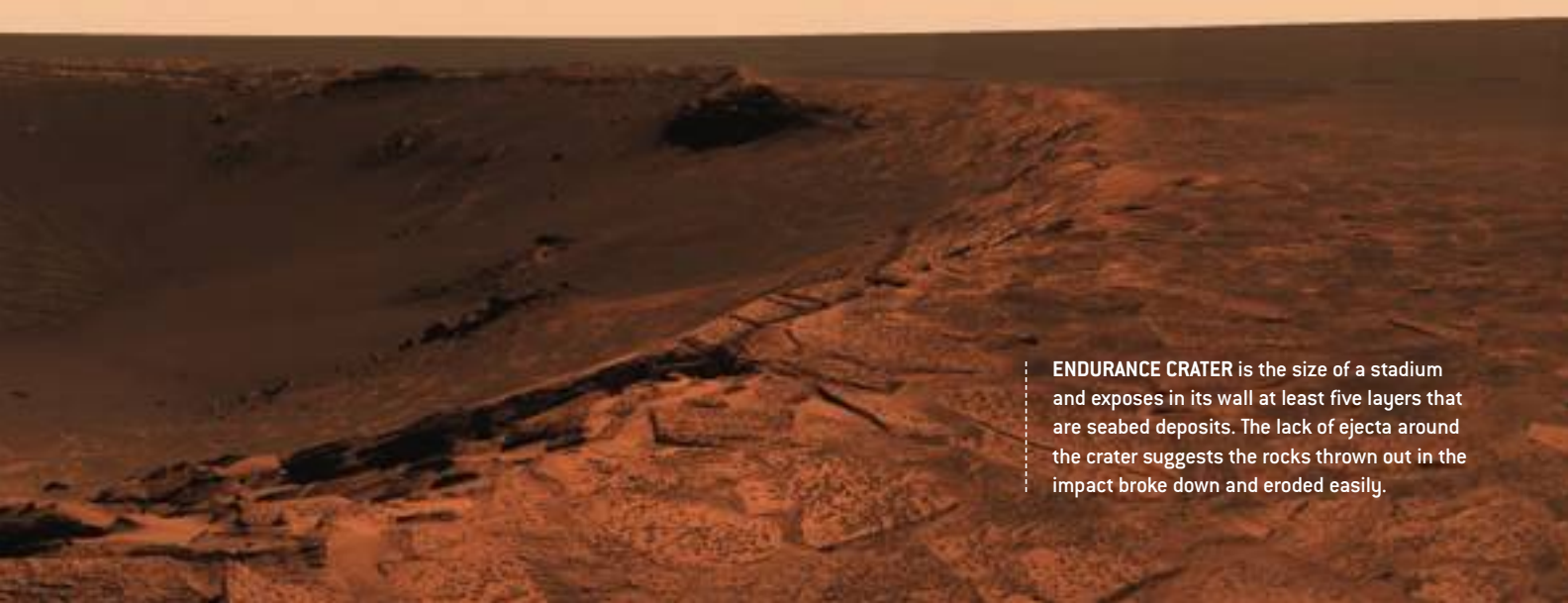
THE SITE CALLED KARATEPE (left) offered Opportunity its safest route down into Endurance. At Karatepe, layers exposed in the inaccessible Burns Cliff (right) lie only 20 feet below the rim and on a slope the rover can handle easily. By staying mostly on rock surfaces, Opportunity maintains good traction. **GARISH HUES** in the false-color image (right) help scientists sort out the composition of the cliff layers. Bright blue indicates basaltic rock or sand, dark green is iron oxide (rust) mixed with basalt, and reds and yellows mark dusty material containing sulfates.The top layer here is exposed in Eagle Crater also.







INSIDE ENDURANCE, (left) Opportunity crept down to investigate layers exposed at Karatepe. Scientists have identified five layers so far, with the A layer being the same as that exposed in Eagle and on the rim of Endurance. **EXAGGERATED FALSE COLORS** (center) help scientists spot subtle differences in rock compositon. The bright red powder shows where the rover's grinder sliced through hematite-bearing blueberries. All the exposed layers are rich in sulfate, but their differences point to changes in the martian environment over time. **BLUEBERRIES AND FRAGMENTS** (right) fill the contact between two layers.



ENDURANCE CRATER is the size of a stadium and exposes in its wall at least five layers that are seabed deposits. The lack of ejecta around the crater suggests the rocks thrown out in the impact broke down and eroded easily.

makes them older) than the outcrop in Eagle. The layers also form steep cliffs in places.

To drive into Endurance, mission planners located one place, dubbed Karatepe, where the lower layers sit only about 20 feet below the rim and the slope tilts some 25° — shallow enough for Opportunity to drive in and back out.

When the rover crept down to the exposed strata, scientists identified at least four additional layers below the Eagle Crater layer. They also proved rich in sulfates generated underwater. But their smooth layering suggests that after they first formed wet, they blew around as dry sediments, mixing thoroughly. Scientists are examining the contacts between layers to see how the environment changed. In the book of Mars, Endurance offers our best look so far at the earlier chapters.

Beyond Endurance

Opportunity is facing the same seasonal change as Spirit. The deepening cold and diminishing sunlight are sapping the rover's capabilities. If Opportunity survives the winter (and escapes Endurance), scientists plan to revisit some sites surveyed only briefly on the dash to the crater. Those sites include Fram Crater (below) and the Anatolia fractures zone.

A few hundred yards away lies the impact site of the rover's heat shield. Studying its remains could help engineers design better ones — and the impact itself will say something about Meridiani's surface materials. Still farther, Opportunity could visit some "etched terrain" about a mile and a half to the south. It may preserve additional stratigraphic layers.

All in all, many great things lie ahead. As Steve Squyres said when Opportunity dove into Endurance, "It's as if our rover missions are starting all over again."

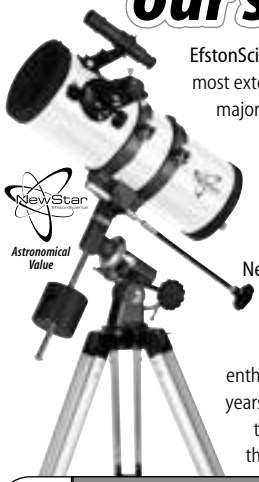
RIPPLES IN THE ROCK may indicate this layer was deposited underwater. The photo was made by Opportunity's microscopic imager and is a mosaic of images taken on the southeast rim of Endurance. The round cavity shows where a blueberry broke free of the rock matrix.

"PAVING BLOCKS" of sulfate rock cover the rim of Endurance. Between the rocks is basaltic sand, while blueberries scatter everywhere.

MOVING VIOLATION? Opportunity's auto-navigator looks like it can't steer, but such tests let mission controllers develop more efficient operations.

FRAM CRATER spans only 22 feet and is likely a secondary impact from another crater's formation. Fram has ejecta (unlike Endurance) because it is smaller and probably younger.

Bright. Sharp. Focused. and that's just our staff.



EfstonScience has Canada's most extensive selection of major brand telescopes, binoculars and astronomy accessories, including our exclusive line of NewStar telescopes. And since we've been serving astronomers and enthusiasts for over 32 years, we're likely to be the brightest thing this side of the sun.

EfstonScience
The Science & Astronomy SuperStore
TOLL FREE (888) 777-5255 www.telescopes.ca

KB MINI TRIPOD SET

LIGHT WEIGHT
*
COMPACT PORTABLE VERY RIGID

$295.95

MORE MODELS ON WEBSITE

WWW.KBSYSTEM.COM
800-423-9677

STARLAB
Portable Planetarium

Learning Technologies, Inc.
40 Cameron Avenue • Somerville, MA 02144
Tel: 800-537-8703 • Fax: 617-628-8606
E-mail: starlab@starlab.com • www.starlab.com

Swinburne Astronomy Online

- **Online Courses in Astronomy:**
  Designed for amateur astronomers, science educators, and anyone with a love of astronomy, Swinburne Astronomy Online is interactive astronomy education featuring custom-made CD-ROMs, newsgroup discussions and informed commentary on the latest astronomy headlines.
- **Programs:**
  We offer Master of Science in Astronomy and Graduate Diploma of Science in Astronomy programs, individual unit enrollment and a six-week short course, all online and accessible worldwide. Visit: **www.astronomy.swin.edu.au/sao/shortcourse**

SWINBURNE
CENTRE FOR ASTROPHYSICS AND SUPERCOMPUTING

For more information, visit www.astronomy.swin.edu.au or contact
Dr. Sarah Maddison at **email:** astro@swin.edu.au **fax:** +61 3 9214 8797
airmail: BSEE, H31, Swinburne University of Technology,
PO Box 218, Hawthorn VIC 3122 Australia

33525

ATOMIC TIME
1010 Jorie Blvd. #332
Oak Brook, Il 60523
1-800-985-8463
www.atomictime.com
Office School Clock #1
WT-3121A $39.95
Atomic Digital Wristwatch
H15U $34.95
H15U
WT-3121A
Areron Atomic Watch
56G24-4 $249.99
56G24-4
1-800-985-8463
www.atomictime.com
WS-8007U-C
LaCrosse Digital Wall Clock $34.95
Tell time by the U.S. Atomic Clock - The official U.S. time that governs ship movements, radio stations, space flights, and warplanes. With small radio receivers hidden inside our timepieces, they automatically synchronize to the U.S. Atomic Clock (which measures each second of time as 9,192,631,770 vibrations of a cesium 133 atom in a vacuum) and give time which is accurate to approx. 1 second every million years. Our timepieces even account automatically for daylight saving time, leap years, and leap seconds. $7.95 Shipping & Handling via UPS. (Rush available at additional cost) Call M-F 9-5 CST for our free catalog.

NASA blasts a comet in the name of science. /// BY JOHN SHIBLEY

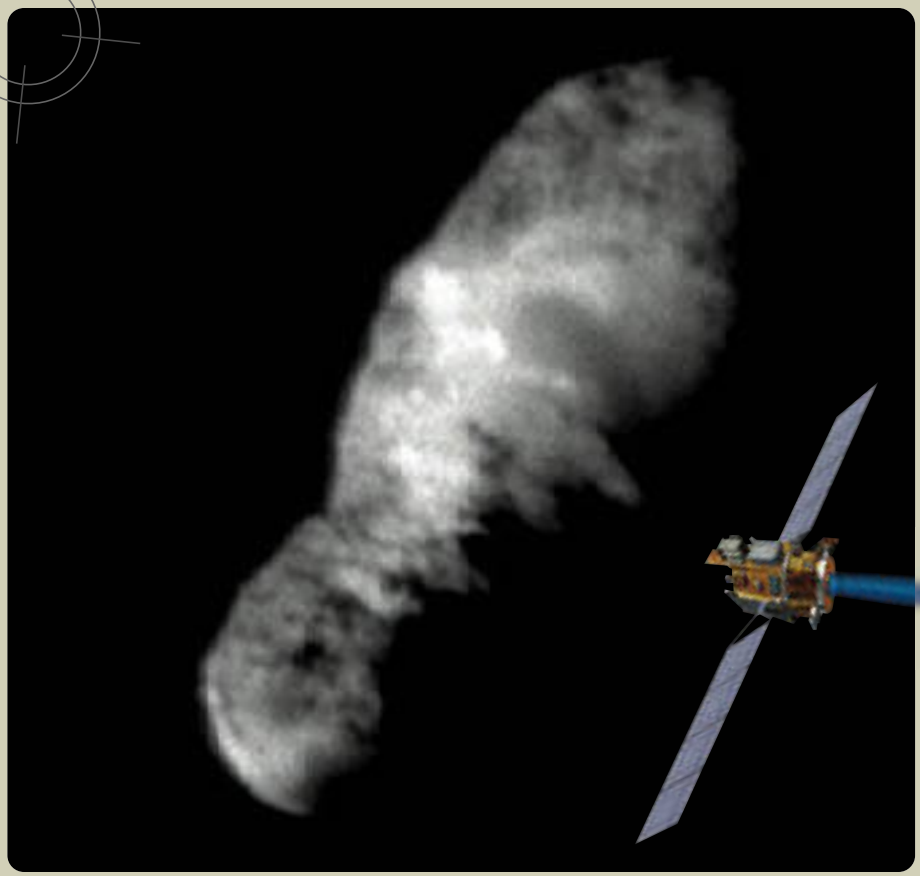
DEEP IMPACT delivers a HI

SPACECRAFT ENCOUNTERS WITH COMETS ARE HARDLY NEW. During the past twenty years, seven craft have bolted past five comets for quick looks. In 1985, a retargeted NASA solar probe swept through the coma and tail of Comet Giacobini-Zinner. In 1986, Europeans, Japanese, and Russians dispatched four spacecraft to fly past Comet Halley. One of them, the European Space Agency's Giotto spacecraft, passed within 120 miles (200 kilometers) of Halley to return humanity's first close-up look at the solid center of a comet. In 1992, the spacecraft went on to fly past Comet Grigg-Skjellerup.

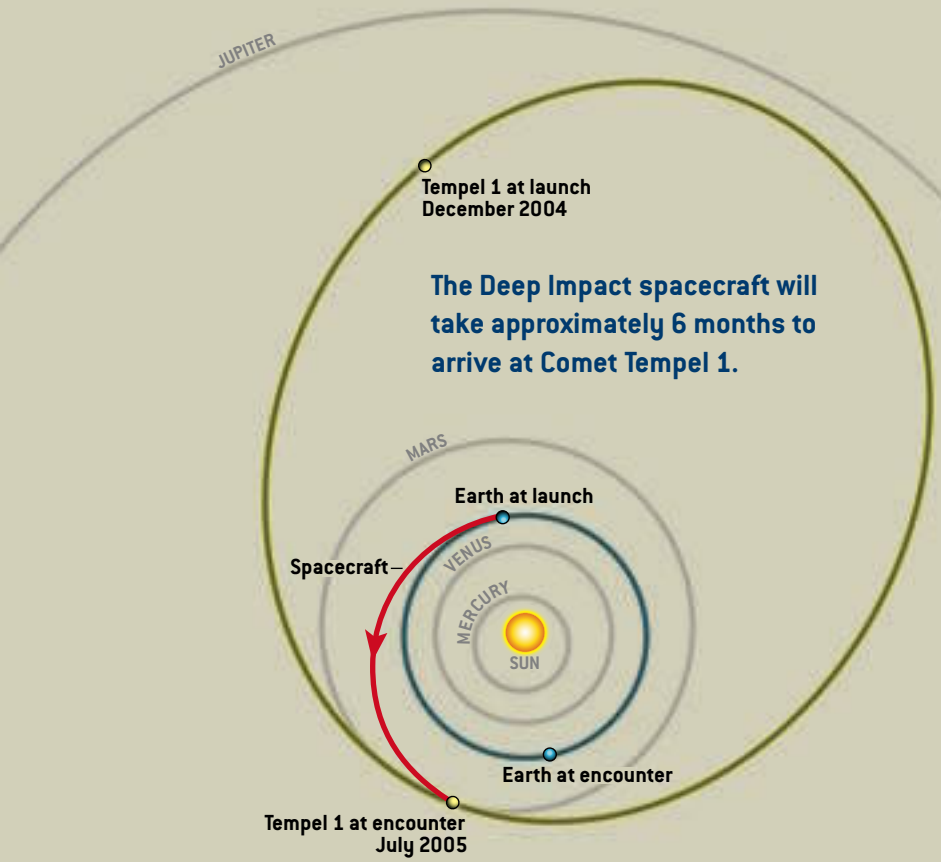
Humans didn't get another close look at a comet's nucleus until 2001, when a spacecraft — Deep Space 1 — launched primarily to test emerging technologies delivered a science bonus by flying 1,350 miles (2,200 km) past Comet Borrelly. Deep Space 1's camera revealed a peanut-shaped body the size of Mount Everest covered with splotches of light and dark material.

In January 2004, NASA's first successful dedicated comet mission, Stardust, not only flew to within 180 miles (300 km) of its target comet, Wild 2, but also extended a sample paddle to capture dust particles and motes given off by the comet's active nucleus. The sample will return to Earth inside a capsule in February 2006, when it will be distributed around the world for laboratory analysis.

COMET TEMPEL 1 is the target of the impactor launched by the Deep Impact spacecraft in this artist's conception. *ASTRONOMY:* ROEN KELLY



DEEP SPACE 1 (right) was launched on October 24, 1998, and made its closest encounter with Comet Borrelly (left), on September 22, 2001. This image shows the 5-mile-long (8 km) nucleus of the comet from a distance of 2,000 miles (3,200 km). NASA



But in 2005, a spacecraft will go one step further. A mission dubbed Deep Impact will reach out and literally *smack* a comet. Its goal is to create a fresh crater on the surface of a comet for scientists to study.

Mission to touch a comet

The Deep Impact mission is scheduled to launch from Cape Canaveral, Florida, in December 2004 for an encounter with Comet Tempel 1 on July 4, 2005. Deep Impact is actually two spacecraft in one: a flyby ship and an 800-pound (370-kilogram) drop-probe impactor. Twenty-four hours before closest approach, the mother ship will release its payload to the surface of Comet Tempel 1. The projectile will hit at 6.3 miles per second (10.2 km/sec) with the energy of 4.8 tons of TNT.

The impactor's kinetic punch is thanks to a 220-pound (100-kg) "cratering mass" of solid copper. The impactor's flight control system will tweak its trajectory to hit exactly where mission planners want to create the crater on Tempel 1. A guiding "impact targeting sensor" should return stunning photos during its approach.

The mother ship, with its modest battery of scientific instruments, will sail by and watch the impact's fireworks from a safe distance of 300 miles (500 km). It will carry cameras that will capture images on approach, when the impactor hits, and during flyby. Both imagers are fitted with filters designed to help identify the spectral signatures of minerals and ices. The high-resolution imager's infrared sensitivity also will capture the heat signatures of certain materials on the comet's surface, in the freshly blasted crater, and within ejecta created by the impactor. Imagers also should collect a bonanza of data from the dust cloud around the comet. On closest approach, the high-resolution camera should resolve details on the comet's surface as small as 20 feet (6 meters) per pixel on the camera's electronic sensor chip. At this scale, the impactor's crater should appear between 60 and 100 pixels across in the camera's field of view.

All told, the impact encounter will be brief. From impactor hit through crater formation to a flyby glance, the mother ship will have slightly more than 13

John Shibley, *a fan of the space program, loves to observe comets. He is also a contributing editor of* Astronomy.

minutes to collect its data. The crater event will take about 200 seconds to unfold.

On Earth, we'll follow events in near real time. It will take only about 7½ minutes for radio signals traveling at the speed of light to reach Earth.

Don Yeomans, who works at NASA's Jet Propulsion Laboratory, calculates that Deep Impact's punch will change the comet's speed by a miniscule 0.000004 inch per second (0.0001 millimeter per second). This will decrease the comet's closest-approach distance to the Sun (perihelion) by 33 feet (10m) and will reduce its orbital period by less than a second.

Punched-up science

Why bother to hit a comet? To see what lies beneath, the thinking goes.

For billions of years, a comet's surface is "seasoned" during its travels through interplanetary space. Short-period comets like Tempel 1 alternately freeze and thaw as their orbits carry them into the outer solar system's colder depths and then into the Sun's warmth again. With each close pass by the Sun, a comet's icy body boils and geysers blast and reshape what started out as a pristine surface. Over time, this freeze-thaw cycle creates a crusty veneer under which older, relatively unmodified material resides.

Scientists want to know just how thick this crust layer is. A thick cap of weathered material protects the volatile ices underneath and ultimately affects how long it takes a comet to erode. By the same token, a thinner, protective layer would mean that comets are not the pristine repositories of early solar system material that scientists hope they are.

Whether the outer layer is thick or thin, just looking at freshly exposed ice on a comet's surface is something astronomers have never had the chance to do. The spectral features of pristine ice will speak volumes about how the comet formed. The relative amount of volatiles, such as methane and ammonia, bound in the exposed ice will open a window to how cold it was in the early solar system.

Aside from opening a hole in the comet's crust to peer into with the spacecraft's cameras, the act of impacting a comet is a unique physics experiment. The crater's size and appearance will yield important clues about the comet's surface strength and mechanics.

MORE THAN 625,000 NAMES will fly along with Deep Impact, thanks to a free, public sign-up NASA created through the Internet. Here, a technician attaches the CD-ROM that contains the names to the "mother ship" part of the spacecraft. NASA

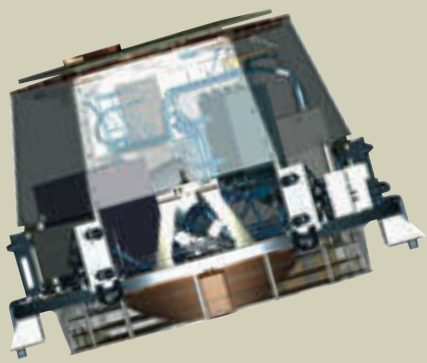
If the comet's surface is tough and weathered, the crust might stand up to the force of the impactor and form a crater with a small ejecta blanket. If Tempel 1 turns out to be porous, the impact could be absorbed and dissipated to create a somewhat smaller, but very deep, crater. Scientists expect the crater will be no wider than 330 feet (100m) and no deeper than 80 feet (25m).

Features in any ejecta blanket that forms also will shed light on the comet's crust and what lies beneath it. Deeper (presumably pristine) material will land closer to the crater. Older material that composes the crust will be blasted farther away.

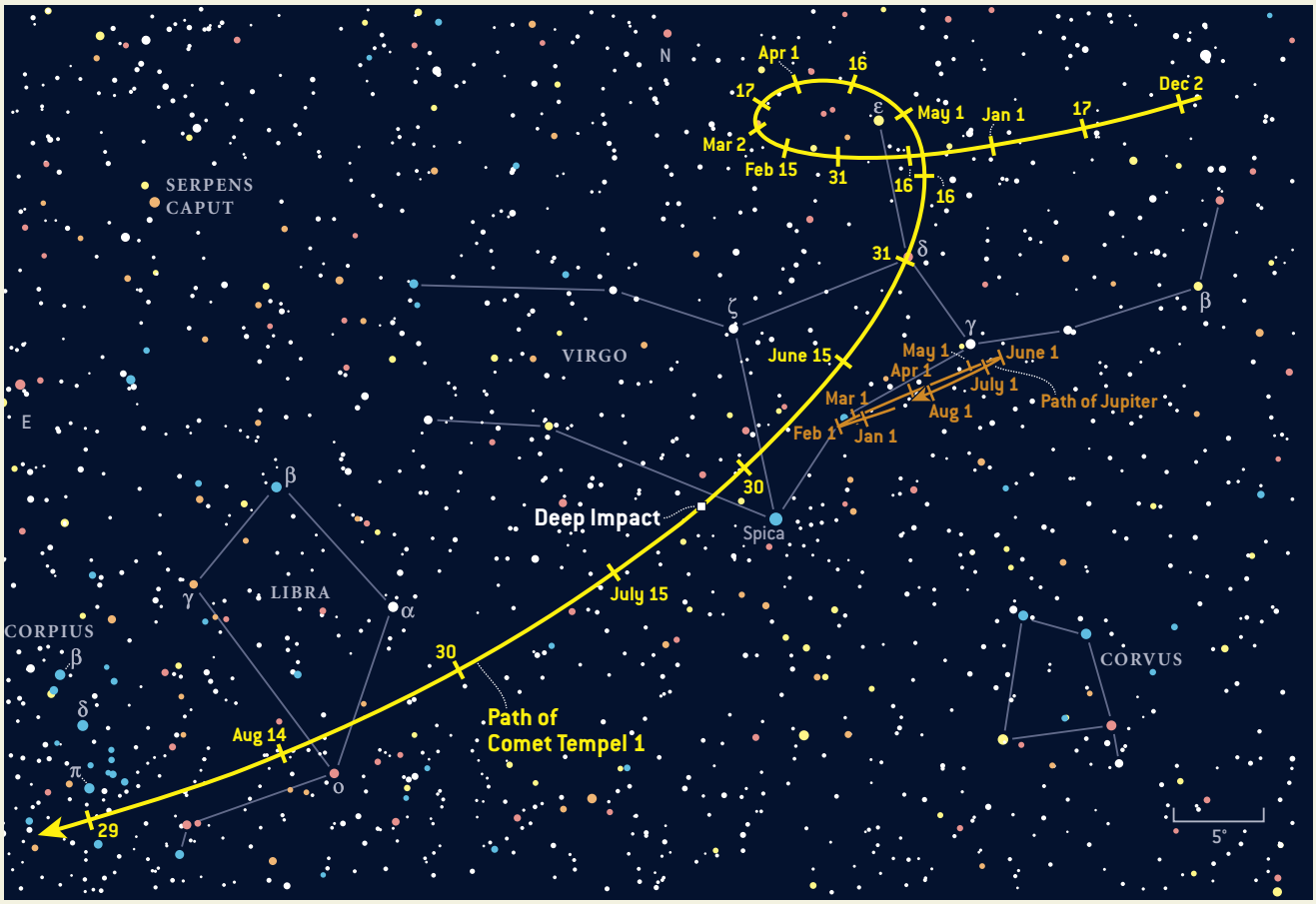
A Rubicon called Tempel 1

Tempel 1 isn't a fresh comet by a long shot. It's spent the past 300,000 years or so in an orbit that takes it from near Jupiter's orbit to just inside Mars's. Indeed, it was probably a relatively close encounter with Jupiter that changed Tempel 1's orbit from a period of several thousand years to its present-day 5½ years.

In 1881, less than twenty years after its discovery in 1867 by German astronomer Ernst Tempel, Jupiter changed the comet's orbit. Two more Jupiter encounters — in 1941 and 1953 — modified the comet's orbit even more. After its discovery appearance, astronomers didn't recover the



DEEP IMPACT'S "IMPACTOR" SPACECRAFT is designed to be released from the main part of the spacecraft and crash into Comet Tempel 1 at a speed of 23,000 miles per hour (10 km/sec). By measuring the crater that will be formed by the 820-pound (370 kg) impactor, astronomers will develop better theories of cometary composition. NASA



While the Tempel 1/Deep Impact action is happening in space, you can be right in the middle of it from your backyard.

Tempel 1 spends the early part of 2005 skirting the northern fringes of Virgo and the southern edge of Coma Berenices. It starts out the year astonishingly faint, glowing feebly at magnitude 15.4. Observers who have telescopes with apertures 17 inches or larger will find such faint quarry a challenge. On the other hand, observers with an 8-inch scope fitted with a CCD camera will find Tempel 1 a moderately easy target to image, even when the comet is this faint. Moonlight-free nights during early 2005 fall between January 5 and 14, and between February 2 and 14.

Between March and late April, Tempel 1 traces out a lazy retrograde (westward) loop in northern Virgo. Earth's orbital motion makes the comet backtrack along its path between March 16 and April 26. Opposition, when Earth lies directly between Tempel 1 and the Sun, occurs in late March.

For planets, opposition usually heralds an object's brightest appearance in Earth's night sky. Remember, though, that this is a tiny object with a solid surface no more than a few miles in diameter. Sunlight reflected by such a tiny chunk of ice is negligible; a comet's brightness comes from a coma of glowing gas and sunlight-scattered dust given off when it's active. Peak activity for Tempel 1 won't happen until July, when it's closest to the Sun.

Tempel 1's region of the sky is high in the east after sunset during March and April. During those months, Tempel 1 gets closer to the Sun and its distance from Earth decreases. Consequently, its magnitude climbs from 12.3, a visual challenge in a 10-inch scope, to magnitude 10.9, more squarely in the realm of what you can spot in an 8-inch instrument on a clear, dark night. Tempel 1 breaks the magnitude-10 barrier on April 23. Moon-free nights in April and May occur between April 1 and 13, and between April 30 and May 12.

By May and June, the region of Virgo that harbors Tempel 1 stands high in the south after evening twilight. During this time, the comet's brightness creeps up from magnitude 9.8 on May 1 to magnitude 9.5 on June 30. Viewing geometry between Earth and Tempel 1 makes it appear at its brightest — magnitude 9.3 — on the evenings of June 8 through June 12. However, the best time to see Tempel 1 may be prior to June 10, before light from a waxing crescent Moon invades the evening sky.

Tempel 1's apparent daily motion in the sky during May, June, and into July will speed up as Earth draws closest to it and then moves away during the period when the comet makes its closest approach to the Sun.

Tempel 1 will be a pretty average sight as far as telescopic comets go. At no time during this apparition will it grow bright enough to become visible to the unaided eye. At its brightest in early June, some eagle-eyed observers might catch a hint of its fuzzy appearance through 7x50 binoculars. More pleasing will be the comet's view through a 6-inch telescope, through which it will look like a fuzzy star. High magnification may reveal an oblong shape as the comet makes its closest approach to the Sun on July 5.

Will you be ready to do some science? Deep Impact mission planners are reaching out to backyard astronomers for help in monitoring the comet during the time leading up to impact. Through a program called Small Telescope Science, planners are looking for images of the comet's nucleus that might help establish what environment awaits the spacecraft. Point your Internet browser to *deepimpact.astro.umd.edu/stsp* for more information about the effort and its technical requirements.

COMET WILD 2'S GLOWING NUCLEUS is (at this writing) the best image ever created of a comet. The Stardust spacecraft made this composite image on January 2, 2004. The nucleus is only about 3 miles (5 km) in diameter, but the jets of dust and gas (not shown) may be millions of miles long. Stardust is scheduled to return a sample of the comet's dusty surroundings to Earth in February 2006. NASA

comet until 1967, and only then after an astronomer computed where it ought to be after all those jovian encounters.

We now know that Tempel 1 is locked into an orbital cycle, called a "resonance," with Jupiter. The comet completes roughly two orbits of the Sun to Jupiter's one. This means Tempel 1 will have more close encounters with its giant-planet benefactor. Someday it may pass too close and suffer the same fate of another Jupiter-crossing comet, Comet Shoemaker-Levy 9. In July 1994, it collided with Jupiter after being broken into more than twenty pieces the year before.

All comets like Tempel 1 are remnants of our early solar system. In fact, the early solar system was chock full of them. Comets and rockier chunks of material swept themselves up into the planets we see today. As the planets got bigger, more and more comets and material were gobbled up or ejected gravitationally into the outer solar system — or out of the solar system entirely.

As the biggest planet in our solar system, Jupiter's been responsible for most of the orbit clearing. Today, most of the icy progenitors linger beyond the orbit of Pluto, residing either in the Kuiper Belt or in a cloud of comets called the Oort Cloud that extends nearly a quarter of the way to the nearest star.

Lately, scientists have been studying dark planetoids called Kuiper Belt objects (KBOs). Some KBOs approach the size of our solar system's outermost planet, Pluto. Indeed, many scientists argue that Pluto, as well as several other icy moons found around some gas-giant planets, may be out-of-place KBOs. To settle this question, NASA is mounting a dedicated mission to Pluto and the Kuiper Belt later this decade.

Comets themselves are far smaller than KBOs, and most have their origins far out in the Oort Cloud, beyond the Kuiper Belt. Every now and then, one of these objects gets a nudge, either through a collision with another chunk of ice or through the subtle gravitational pull of a passing star. The comet then starts a million-year fall into the Sun's gravity well, and into the Sun's warmth. This process has been going on for billions of years.

After a long-period pass or two around the Sun, the comet's orbit gets modified either through a close encounter with a gas-giant planet (usually Jupiter) or because of solar heating that causes jet activity on the comet's surface. Either way, a one- or two-million-year orbit is reduced to several thousand years.

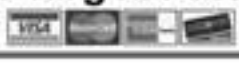
Being at the right place at the right time means still more orbital modifications by a planet. If the comet doesn't get ejected, swallowed up by a gas-giant planet, or directed into the Sun, its orbit gets smaller. Perhaps it forms a gravitational resonance with Jupiter. Down the orbital period goes — to one hundred years, fifty years, a dozen years, until finally, the comet joins a family of short-period comets like Tempel 1.

Out of the millions of comets that have passed through the solar system, circumstances have created only a few dozen with periods short enough to allow humans to reach them with a spacecraft. One of these comets is Tempel 1, and Deep Impact mission scientists are dreaming about what lies just beneath its surface. A

SCOPETRONIX
QUALITY ASTRONOMY PRODUCTS

PHONE/FAX
(239) 945-6763
WWW.SCOPETRONIX.COM

Florida's largest stocking telescope dealer!

We Accept  Telescopes, Accessories & much more!

Visit our website for Meade, Celestron and Tele Vue Telescopes!

Meade | TeleVue Visionary | CELESTRON

ScopeTronix Digital Camera Solutions

We have the worlds largest selection of digital camera adapters

Moving up to a Digital SLR camera?

The MaxView-DSLR is for you!

DSLR II shown on a Canon 10D"

NEW! Hot Product!

Finally a variable projection adapter large enough to hold ANY eyepiece! Now you can use your best eyepieces for astrophotography. The picture at right shows the 1.25" version (left), the 2" version (right) and a standard sized projection adapter between them for scale. The 1.25" version will accept any 1.25" eyepiece. The 2" version will accept any 1.25" or 2" eyepiece...yes even a 31mm Nagler! Both versions include a removable MaxPower lens to increase magnification and allow use in scopes with very little back focus. These are variable length adapters allowing you to adjust the magnification in small increments to fill the frame. Change eyepieces in seconds. Machined from solid aluminum, anodized black with a knurled grip ring. 2" version includes 1.25" adapter. Both units are T threaded for use with standard T-Rings. Can be used with 35mm SLR cameras too! *Camera not included.

1.25" MaxView-DSLR 2.00"

1.25" *MaxView-DSLR* (STSLR1) $129.00 | 2" *MaxView-DSLR* (STSLR2) $189.00

MaxView™ & MaxPower™ Lenses

Our award winning MaxView 40 and new MaxView II Digital Camera Adapters are specially designed eyepieces for use with digital cameras. Designed to give the least vignetting, even when used with large lensed cameras. The MaxView 40 is 1.25" format while the MaxView II is 2" format. We carry dozens of adapter kits to fit either MaxView to most all digital cameras with threaded lenses. Our new MaxPower™ lenses thread into the bottom of the MaxView eyepieces to increase magnification by 60% while maintaining the desirable properties of the MaxView eyepieces. We also have versions made specifically for use with Microscopes and most popular nature scopes such as Swarovski, Pentax, Leica, Zeiss and more! **Patent Pending.**

New 2" MaxView II!

1.25" MaxView 40

MaxView 40™ 1.25" 129.95
MaxView II™ 2.0" 189.95

MaxPower Booster Lens
MaxPower 1™ 1.25" 39.00
MaxPower 2™ 2.0" 69.00

Awarded "Hot Product" SKY & Telescope Magazine 2003

MaxPower Boosters!

The Digi-T™ System

The world's best selling Digicam Adapter!

*Patent Pending

The Digi-T system allows you to use most popular plossl eyepieces with your digital camera. We have dozens of kits to fit all popular digital cameras. *See complete details on our website.*

Pricing from $59.95 to $109.95

Fits: Meade Super Plossls, Celestron NexStar Plossls, ScopeTronix ST Series, Orion Sirius Plossls, and many more eyepieces with removable rubber eyeguards.

Add GPS to your Scope!

Easy to install unit adds GPS functionality to many scopes. Versions to work with Meade ETX, LX90, LX200 (GPS and Classic), Losmandy Gemini, and Astro-Physics GTO. No more entering the time, date, and location! It is all entered for you at very high accuracy! See our website for full details and model number for your particular telescope.

STARGPS $169.00

WebCam Adapters

All adapters fit 1.25" focusers

We carry adapters to attach most popular webcams and "C" mount security cameras to your telescope. See our website for your specific camera models.

STWCA1 Fits Toucam,Creative WC Pro, more **29.95**
STWCA2 Fits QuickCam, 3com and more **29.95**
STWCA3 Fits Vestra Pro, Kensington, more..... **29.95**
STC125 Fits all "C" Mount cameras..... **22.95**

Wide Angle Eyepiece & Digital Camera Adapter for Nikon 950/990/995/4500

These 1-1/4" Wide Angle 60+ degree Apparent Field View eyepieces can also be used as a fine visual eyepiece, but unthread the eyeguard to reveal a 28mm threaded adapter that allows it to be mounted to any digital camera with a 28mm lens thread! A 28 to 37mm adapter is also available.

STWA14 14mm... 109.00 | STWA18 18mm... 99.00

The ScopeTronix EZ-PIX™ Universal Digital Camera Adapter

No lens thread on your digital camera? No problem! Our universal design fits any camera with a standard 1/4-20 threaded mounting hole. The padded eyepiece clamp slips over most Plössl eyepieces and barlow lens. The EZ-PIX is the original universal camera adapter, don't be fooled be cheap imitations that claim to be of an improved design. *The EZ-PIX is still the best design available!* Spacer included (shown at right)

Now includes two padded clamps to fit a wide variety of eyepieces!

STEZPIX Universal Digital Camera Adapter..... **49.95**

NEW Product!

4 in 1 Multi-Mate Alignment Tool

The ScopeTronix Multi-Mate is four handy devices in one compact inexpensive unit. Great for GOTO scope setup. Insert it into your eyepiece holder and use the bubble level to quickly and accurately level your optical tube. Flip it over and use the handy compass to quickly find North. When your scope is in storage it acts as a dust plug and in addition it contains a replaceable bag of desiccant to protect your scope in storage. The desiccant draws moisture out of your OTA through small holes around the compass and traps it in the desiccant chamber. This helps prevent optical damage due to moisture and mold formation. **STMM** 4 in 1 Multi-Mate... **$24.95**

CrystalVue Optics Sharp Shooter 8x32mm Monocular and Telephoto Digital Camera Lens

8x32mm monocular converts to a telephoto lens for digital cameras. Remove the rubber eyeguard to reveal a 37mm lens thread. Includes a 28mm to 37mm adapter ring. **CVOSS**..... **149.00** (Shown with Coolpix 995)

ScopeTronix Thread On Solar Filters for ETX & Tele Vue scopes

Custom machined black aluminum filter cell securely threads onto telescope

STSF60	fits ETX60 and ETX70	64.95
STSF90	fits ETX 90	84.95
STSF105	fits ETX 105	94.95
STSF125	fits ETX 125	99.95
STSF76	fits Tele Vue 76 ...NEW!	79.95
STSF85	fits Tele Vue 85 ...NEW!	89.95
STSFB	fits Canon 50mm IS(2)	99.95

ScopeTronix ST Series Plössl Eyepieces

STPL04	4mm ST Series Plössl	37.95
STPL06	6mm ST Series Plössl	37.95
STPL09	9mm ST Series Plössl	37.95
STPL12	12mm ST Series Plössl	37.95
STPL15	15mm ST Series Plössl	37.95
STPL20	20mm ST Series Plössl	37.95
STPL25	25mm ST Series Plössl	37.95
STPL32	32mm ST Series Plössl	42.95
STPL40	40mm ST Series Plössl	42.95
STPLSET	Complete Set (9)	349.00

ScopeTronix Barlow Lenses

STBAR2	2x	39.95
STBAR3	3x	42.95
ST2BAR2	2x 2"	79.95

Color Filter Set For 1.25" Eyepieces

$37.95

4 piece set includes Red #23A Yellow #12 Blue #80A Green #58A

ScopeTronix Eyepiece Bottles & Filter Cases

We now stock 6 different size eyepiece bottles to fit almost any size eyepiece!

ScopeTronix "Bolt-Style" Eyepiece Bottles

STEP01	Eyepiece Bottle - 1.4" ID, 1.9-2.6" Length	3.00
STEP02	Eyepiece Bottle - 1.6" ID, 3.2-4.7" Length	3.00
STEP03	Eyepiece Bottle - 2.0" ID, 3.2-4.7" Length	4.00
STEP04	Eyepiece Bottle - 2.0" ID, 3.2-4.7" Length	5.00
STEP05	Eyepiece Bottle - 2.5" ID, 4.7-7.8" Length	6.00
STEP06	Eyepiece Bottle - 3.1" ID, 4.7-7.0" Length	7.00

ScopeTronix Filter Cases

STBOXS	Small (1-1/4" filter size box)	1.95
STBOXL	Large (reducer/corrector size box)	2.95

Parfocal Rings

Make your EP's parfocal!

1.25" STPRING		7.95
2.0" STPRING2		8.95

1.25" Extension

STEPEXT 12.95

Extends 1.25" EP barrel by 1 inch. Threaded for filters or stacking.

ScopeTronix ETX & NexStar Piggy Back Camera Mounts

STPB70	ETX-60/70AT	42.95
STPB90	ETX-90EC/RA	49.95
STPB125	ETX-125EC	64.95
STPBN5	NexStar 5	59.95

ScopeTronix Tripod Adapter & Accessory Holder for ETX

Deluxe Tripod Adapter

Fits ¼" & 3/8" tripods. Holds Autostar & 4 Eyepieces **STDXTRAD 96.95**

Accessory Tray for ETX

STTRAY90 ETX90 ... 59.95
STTRAY105 ETX105 .. 59.95
STTRAY125 ETX125 .. 64.95

Accessory Tray mounted to ETX

ScopeTronix Flexi-Focus™ for ETX Telescopes

Oversized knob and flexible shaft allow crisp, sharp focusing even when OTA is pointed straight up!

STFLEX70 For ETX-60/70AT.. **34.95**
STFLEX90 For ETX-90EC/RA **34.95**
STFLEX125 For ETX-125EC.. **34.95**

Flexible shaft reduces vibrations. Achieve sharp focus fast!

ScopeTronix Green Laser Pointer

5mw continuous mode laser beam is easily visible at night! 2 AAA batteries included.

STGREEN 5mw Green Laser Pointer **$189.00**

NEW! ScopeTronix Tripod Bag for LX Tripods

Our quality tripod bags are designed for the Meade field tripod used with the LX series scopes up to 10" such as the LX10/50/90/200/GPS. Features include full interior padding, heavy duty carry handles, an adjustable shoulder strap, color keyed to match the Meade soft case, and an outside pocket sized just right for a set of vibration suppression pads!

STBAGLX LX tripod bag **79.00**

ScopeTronix designs and manufactures many unique products like the patent pending Maxview's, Digi-T, Flexi-Focus, etc... Dealer inquiries are always welcome!

GET THE MOST FROM ASTRONOMY

THE WORLD'S BEST SELLING ASTRONOMY MAGAZINE OFFERS YOU:

- **STUNNING PHOTOGRAPHY** – Our images are so vivid you'll feel like you're there.
- **EXPERT OBSERVING TIPS** – We help you get the most from every moment under the stars, with helpful tips and monthly star charts.
- **READABLE, USER-FRIENDLY ARTICLES FOR ASTRONOMERS AT ANY LEVEL** — We relay the information so you can understand it.
- **INFORMATIVE, UNBIASED EQUIPMENT REVIEWS** – We help you make the best telescope and binocular purchases.
- **TIMELY SCIENCE REPORTING** – We keep you up to date on the latest news in the Solar System and beyond.

Stay informed and get the most from your hobby. Subscribe to *Astronomy* magazine today!

Simply fill out and mail the attached card or call

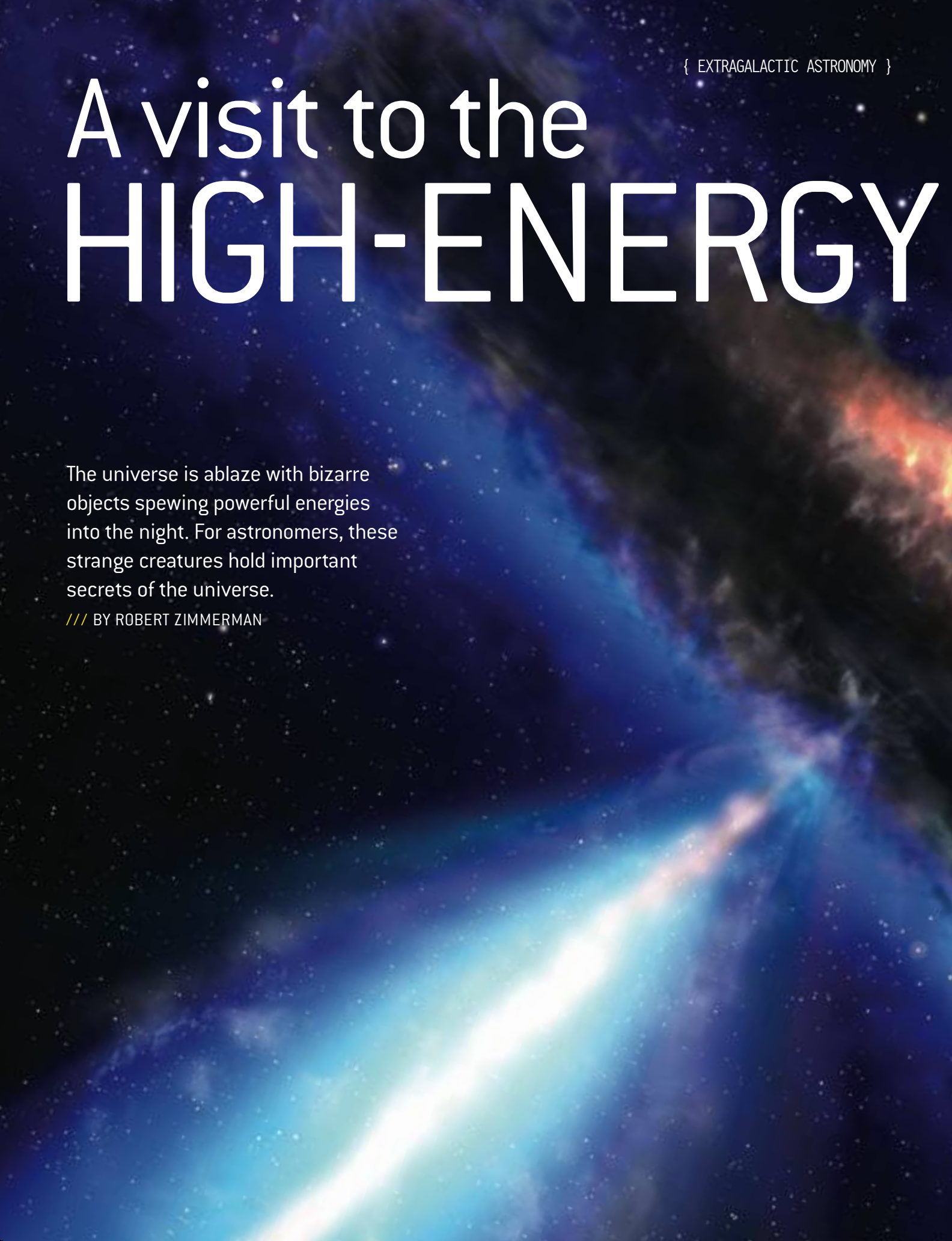
800.533.6644

Mon-Fri, 8:30am-5:00pm CST. Outside the U.S. and Canada, call 262-796-8776.

A49YA

03X1322

A visit to the HIGH-ENERGY



The universe is ablaze with bizarre objects spewing powerful energies into the night. For astronomers, these strange creatures hold important secrets of the universe.

/// BY ROBERT ZIMMERMAN

ZOO

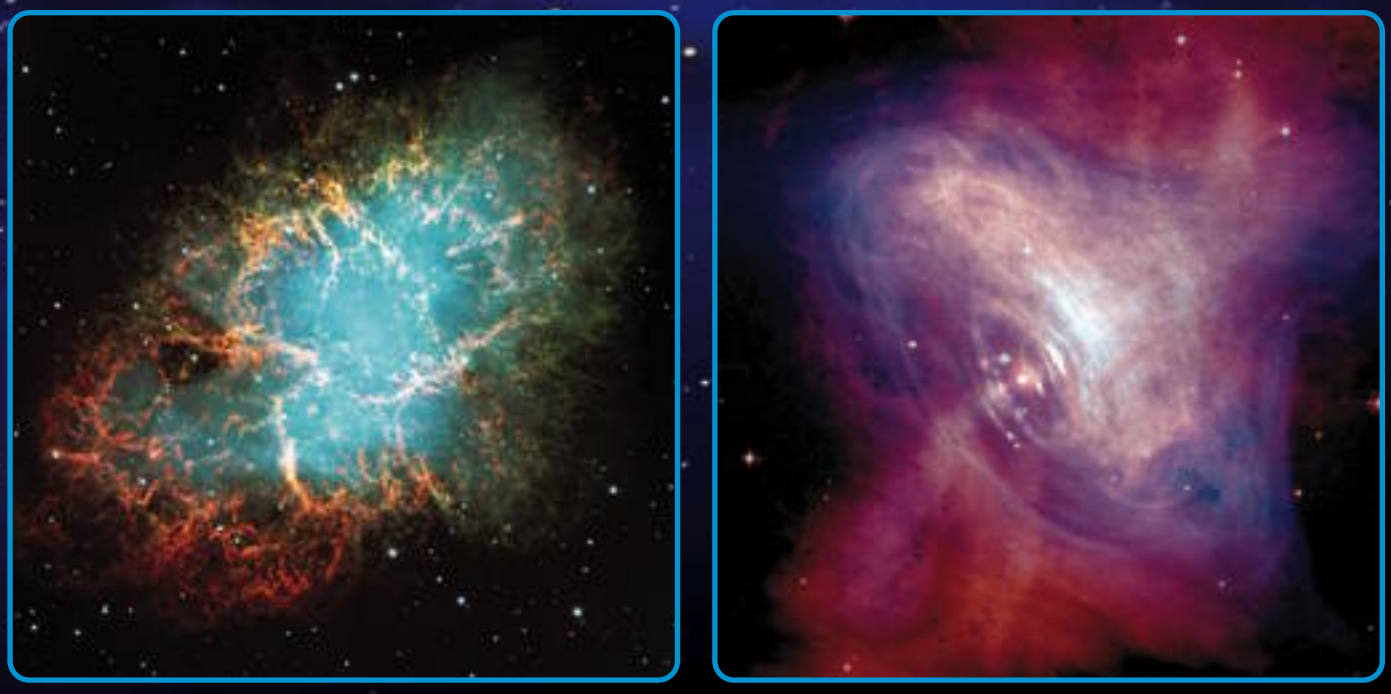
THE STARLIT SKY YOU SEE ON A CLEAR EVENING IS A grotesque illusion. A quiet darkness lit with points of light is just a benign mask covering the real sky, which is littered with thousands of strange astrophysical beasts emitting prodigious amounts of high-energy X and gamma rays.

Some sources come and go, burning brightly for weeks, days, hours — sometimes only seconds — then they fade into oblivion, perhaps for decades. Others throb like clockwork, producing bursts of energy at a rate more precise than any timepiece on Earth. And some burn continuously, forever broadcasting electromagnetic energy so powerfully they make the space around them uninhabitable for hundreds of light-years.

Before the launch of the Uhuru X-ray telescope in 1970, this "zoo" of weird celestial bodies — all of which would kill you if you drew too close — was completely unknown. Despite their apparent variety, these high-energy objects have many elements in common, and all are fundamentally important in understanding the life cycle of stars and galaxies. Without a clear knowledge of how these beasts got the way they are, we cannot comprehend the universe — not even the tiny part of it we live in.

Our tour of the zoo, however, is necessarily incomplete; there are simply too many different things out

A RING OF DUST HIDES A GIANT BLACK HOLE at the heart of a galaxy in this artist's impression. Black holes can range in mass from a few times that of the Sun to millions of times greater. As matter falls into the black hole, gravity squeezes and heats it to enormous temperatures, yielding high-energy radiation and jets that shoot out for light-years. ESA/NASA



A STAR EXPLODED about a thousand years ago, and its tangled filaments — the Crab Nebula — now span 6 light-years (left). At the nebula's heart lies a neutron star spinning 30 times a second. Caught by simultaneous observations made with the Hubble Space Telescope and the Chandra X-ray Observatory (right), the inner parts of the nebula pulse and tremble on a timescale of a few weeks. LEFT: ESO; RIGHT: NASA/CXC/ASU/J. HESTER

there to look at. So instead of trying to see them all, we'll sample some of the more interesting ones.

We begin with one of the closest and most famous. Six thousand light-years away in the constellation Taurus lies the Crab Nebula, the king of all nearby high-energy objects.

The star that created the Crab Nebula went supernova in 1054. It left behind a 6-light-year-wide remnant of dust and ionized gas, twisted like a giant ball of twine, at the center of which lies a 10-mile-wide (16 kilometer) neutron star beating 30 times a second. With each pulse, the star sends out a wave of electromagnetic energy that courses through the surrounding cloud of material, energizing its rings, wisps, blobs, and ionized flux tubes.

What makes the Crab even stranger is its incredible activity. A thousand years after the explosion, some features in the nebula's innermost regions literally dance about from week to week. One blob even has been dubbed the Sprite by astronomers because its shape and position shift so frequently.

All this activity is caused by high-energy jets and waves pouring out from the central neutron star. First are the pulsar's two bipolar jets, punching beams of continuous electromagnetic energy into the cloud and beyond. Because the star tilts 30° to our line of sight, as it rotates, the northern jet swings about like the beam from a lighthouse, flashing in and out of view 30 times a second.

Waves of energy then radiate from the neutron star's equator like ever-expanding concentric rings. As this energy hits the cloud surrounding the star, it produces the light show we see. In 2002, astronomers aimed both the Hubble Space Telescope and the Chandra X-ray Observatory at the Crab and took a sequence of coordinated images over several weeks. The result was a movie showing waves of energy making the Crab's inner cloud pulse and tremble almost like a bowl of Jell-O.

A far more recent supernova is SN1987A. Located in the Large Magellanic Cloud more than two dozen times farther away than the Crab, SN1987A is the only naked-eye-visible supernova to occur in the last four centuries. Today, 17 years after the star blew up, we can watch a dying star evolve into the wild and mysterious nebula and neutron star we see at the Crab.

Early in the aftermath of SN1987A's explosion, a graceful hourglass-shaped nebula appeared. This cloud had formed thousands of years earlier as the star aged and shed material from its outer layers. When the star erupted in 1987, the cloud was lit by the explosive wave of ultraviolet radiation sweeping past.

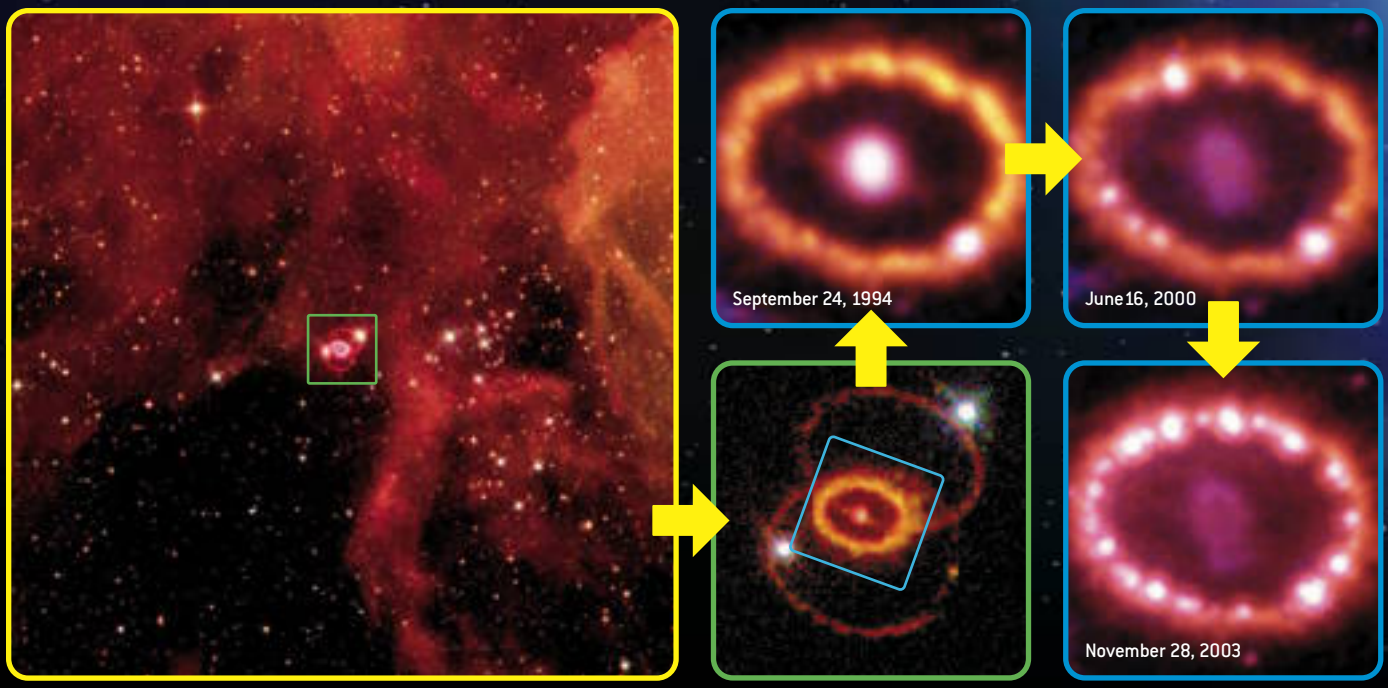
Immediately, the hourglass began to fade. Now, almost 20 years later, the nebula's inner ring, a light-year in diameter, is coming alive again. The shock wave of material flung from the supernova in the explosion has arrived, crashing into it at speeds of more than a million miles per hour. Astronomers began seeing evidence for this in 1996, when the first debris began hitting parts of the ring. By 1999, several spots had brightened significantly and by 2003, the entire ring was a glittering chain of light.

As the shock wave smashes through in the years ahead, the hotspots will grow and merge to form a single fiery ring, glowing at over a million degrees Fahrenheit. By then, astronomers expect it to become bright enough to illuminate other parts of the star's leftover debris. This will provide further information about how stars evolve and become supernovae.

Bizarre pulsar

Both the Crab and SN1987A are examples of young supernovae, relatively recent high-energy events that are still evolving.

Robert Zimmerman *is a regular contributor to* Astronomy. *His most recent book is* Leaving Earth: Space Stations, Rival Superpowers, and the Quest For Interplanetary Travel *(Joseph Henry Press, 2003).*



LOOKING ON FROM A SAFE DISTANCE, astronomers are monitoring the growing shell around Supernova 1987A in the Large Magellanic Cloud, 160,000 light-years away. As the expanding blast wave hits knots of material ejected earlier by the progenitor star, the shock heats them to million-degree temperatures, making a pearly ring. NASA/STScI/CFA, R. KIRSHNER

Scattered throughout the Milky Way, however, are much older stellar corpses.

Among these, GRO J1744–28 is typically atypical. On December 2, 1995, GRO J1744–28 began sending out strong bursts of X-ray energy, one burst about every 3 minutes. By the end of the first day, it had produced more than 140 bursts, and by the end of three months, the burst count exceeded 1,000. A close look at the spot in the sky from where the bursts were coming revealed a previously unknown, ordinary pulsar beating twice per second in radio waves. It was soon dubbed the Bursting Pulsar, and astronomers were baffled. Theory said that pulsing and bursting should be mutually exclusive.

> The microquasar GRS 1915+104 is a strange system that actually seems to meet the mathematical definition of chaos.

Astronomers think all bursters and some pulsars occur in binary systems. These are composed of a neutron star and an ordinary star orbiting each other so tightly that the gravitational field of the more massive neutron star rips gas from the companion's outer layers. The gas is drawn into an accretion disk about the diameter of our Sun that swirls around the neutron star. The pulses and bursts occur whenever material flows from the accretion disk onto the neutron star.

With pulsars, the flow is steady. The pulsar is thought to have a rather strong magnetic field, and the accreting material from the disk therefore funnels down the magnetic field lines to a spot near the pulsar's magnetic pole. As the gas hits the neutron star's crust, it makes the impact point radiate across a range of electromagnetic wavelengths, which we see as pulses because the star is spinning. The Crab neutron star is a good example of this phenomenon (although in the case of the Crab, the material comes from the inner nebula, not a binary companion).

Bursters, however, are thought to have weaker magnetic fields. Instead of funnelling onto a particular point, the accreting material rains gently down across the neutron star's entire surface, building up like a strange kind of snow. When the layer thickens enough, however, it reaches critical mass and literally detonates as a global thermonuclear explosion. The result? X-ray bursts.

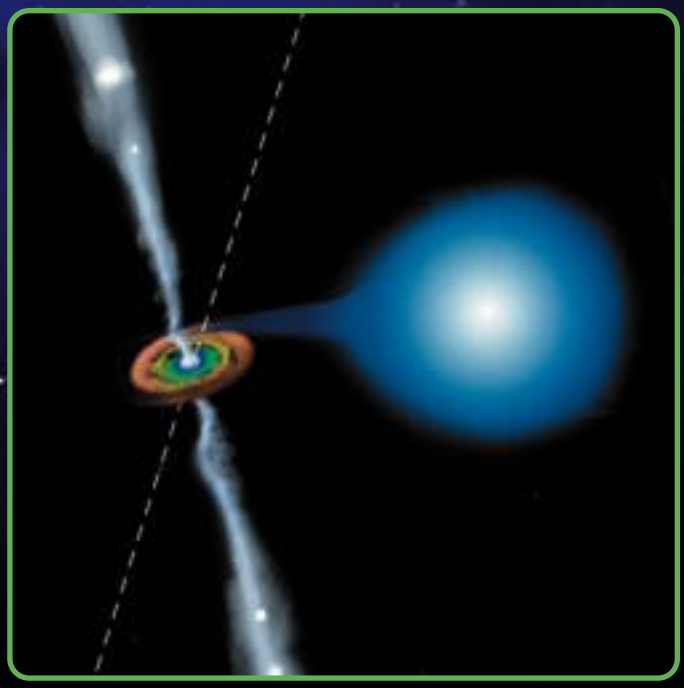
That GRO J1744–28 was doing both made no sense. After some thought, however, John Cannizzo of the Goddard Space Flight Center in Maryland proposed that GRO J1744–28's bursts were caused by a periodic collapse of material from the inner parts of its accretion disk. The disk would become overloaded from time to time and suddenly dump a huge quantity of gas.

Why the Bursting Pulsar would pulse at the same time remains unclear. In subsequent years, except for brief outbursts in 1997, GRO J1744–28 has been quiescent, with both bursts and pulses disappearing. The object is only barely visible to the Chandra X-ray Observatory, and it stands as a baffling mystery.

Microquasars

Larger and fiercer than pulsars and bursters are black-hole microquasars. These resemble miniature versions of the giant quasars

A HIGHLY MAGNETIZED PULSAR, SGR 1900+14 has a magnetic field trillions of times stronger than Earth's. One outburst by SGR 1900+14 in August 1998 compressed Earth's ionosphere. NASA/UNIV. OF ALABAMA ARTWORK



MICROQUASAR SS433 is shooting corkscrew jets in opposite directions. It appears to be a black hole with an evolved star feeding gas into an accretion disk. As the disk precesses, the jets swivel with it. CXC ARTWORK

billions of light-years away. They emit plentiful radiation in all wavelengths, with bipolar jets shooting matter at speeds that, in some cases, appear faster than light. The handful known are located mostly along the plane of the Milky Way. Fortunately for us, none lies closer than 10,000 light-years.

One of the more erratic and puzzling microquasars is GRS 1915+105, first discovered in 1990. A binary system about 40,000 light-years away, this microquasar differs from a pulsar or burster in that its stellar corpse is a black hole. GRS 1915+105, for example, has a black hole of about 14 solar masses, surrounded by a large accretion disk and orbited every 34 days by an older, evolved K-type giant star slightly less massive than the Sun.

steady stream of X rays. But about 10 to 20 percent of the time, GRS 1915+105 hiccups in such a predictable manner that in 1997 astronomers dubbed it "Old Faithful" because it was erupting every 20 to 40 minutes, spewing out a mass about equal to a 100-trillion-ton asteroid at nearly the speed of light. And now, about once a year or so, GRS 1915+105 gives off a giant eruption, an outburst of truly epic proportions.

The best theory astronomers have to explain some of the microquasar's behavior is that the inner parts of the black hole's accretion disk steadily fill with material. When some mass limit is reached, it suddenly dumps the material into the black hole, producing the X-ray outburst.

In August 1998, magnetar SGR 1900+14 emitted an outburst powerful enough to push down the top of Earth's ionosphere 25 miles.

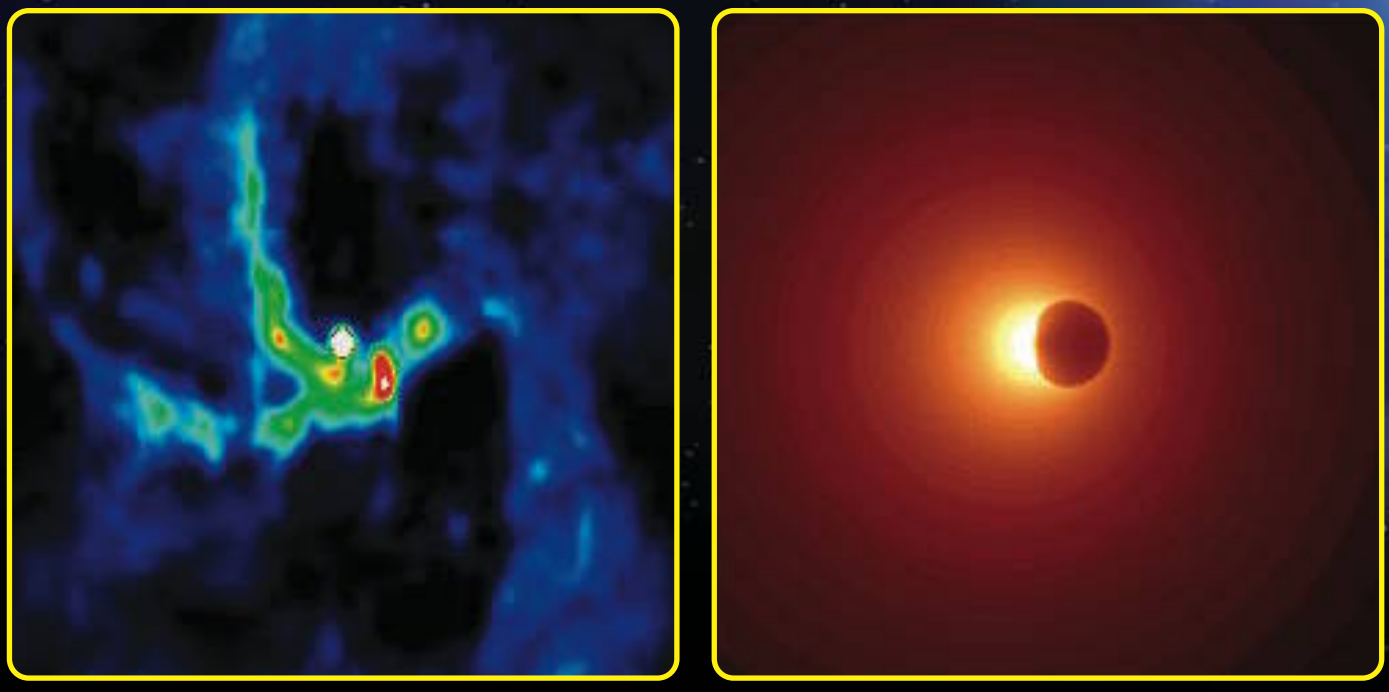
Similar to what happens with pulsars and bursters, the activity at GRS 1915+105 results from the black hole ripping gas from its orbiting companion, dumping it onto an accretion disk, and the subsequent collapse of material into the central black hole. While most of the material disappears into black-hole heaven, a small percentage is ejected from the poles along with bursts of X-ray and gamma-ray emission.

Unlike neutron stars, however, microquasars operate at much higher energies and masses. For example, the jets squirting from GRS 1915+105's poles move at 92 percent the speed of light. At that speed, you could fly to the Moon and back in 3 seconds.

Furthermore, the microquasar emits pulses, burps, and flares almost arbitrarily. Most of the time it just sits there, emitting a

Yet the almost random nature of the bursts makes the system extremely baffling. As Stephen Eikenberry of the University of Florida notes, "The system actually seems to meet the mathematical definition of chaos."

Another equally enigmatic microquasar is the famed SS433, located 16,000 light-years away. First identified in the 1960s, the true weirdness of this object became evident in 1979, when astronomers discovered it has two narrow jets shooting in opposite directions. To astronomers' great surprise, they saw that the material in the jets does not move in straight lines, but in complementary corkscrews above and below the object, as if the jets come from a spinning lawn sprinkler. The jets change orientation over a 163-day period.



SUPERMASSIVE BLACK HOLES lie at the heart of many large galaxies, including the Milky Way. Radio-frequency signals (above left) can pass through the dust hiding the galactic core from view. The Y-shape is tendrils of gas falling toward the central black hole. Recently, radio astronomers imaged the shadow of the central black hole (right). It has a diameter about 100 times the distance from Earth to the Moon. NRAO

Last year, astronomers were able to image the jets flying from the central black hole at speeds about 26 percent the speed of light. They found that as blobs in the jets move outward, they routinely brighten when they reach certain distances. Scientists think the brightening occurs because the blobs are colliding with something, although they are unsure just what it is.

The truth is that unlike GRS 1915+105, much less is certain about SS433. Until recently, most astronomers thought the SS433 system was a neutron star orbited every 13 days by an evolved star that was feeding gas into an accretion disk around its companion. This disk would precess over 163 days. More recent data affirm the orbital period, while suggesting that the central object might instead be a black hole of four to eight solar masses. But exactly what is going on at SS433 remains a mystery.

Magnetars

Even more amazing than the microquasars are the magnetars, solitary neutron stars with what astrophysicists believe are the strongest magnetic fields in existence.

The first hint that such objects exist came with the discovery in the late 1970s of soft gamma-ray repeaters, of which only five have been discovered. These objects, which routinely emit a steady flux of X rays, periodically give off strong bursts of soft (low-energy) gamma rays. At first, scientists thought they were an unusual type of gamma-ray burst. Today, they know different.

According to a theory proposed by Robert C. Duncan of the University of Texas at Austin and Christopher Thompson of the Canadian Institute of Theoretical Astrophysics in Toronto, the bursts are caused by an incredibly powerful magnetic field surrounding a single neutron star. For comparison, Earth's magnetic field has a strength of about 0.6 gauss, while a refrigerator magnet carries about 100 gauss. A magnetar's field, however, is a thousand *trillion* gauss, so powerful that it distorts the shapes of atoms, squeezing electron orbits into thin ellipses, making the atom resemble a needle, less than one percent its normal diameter.

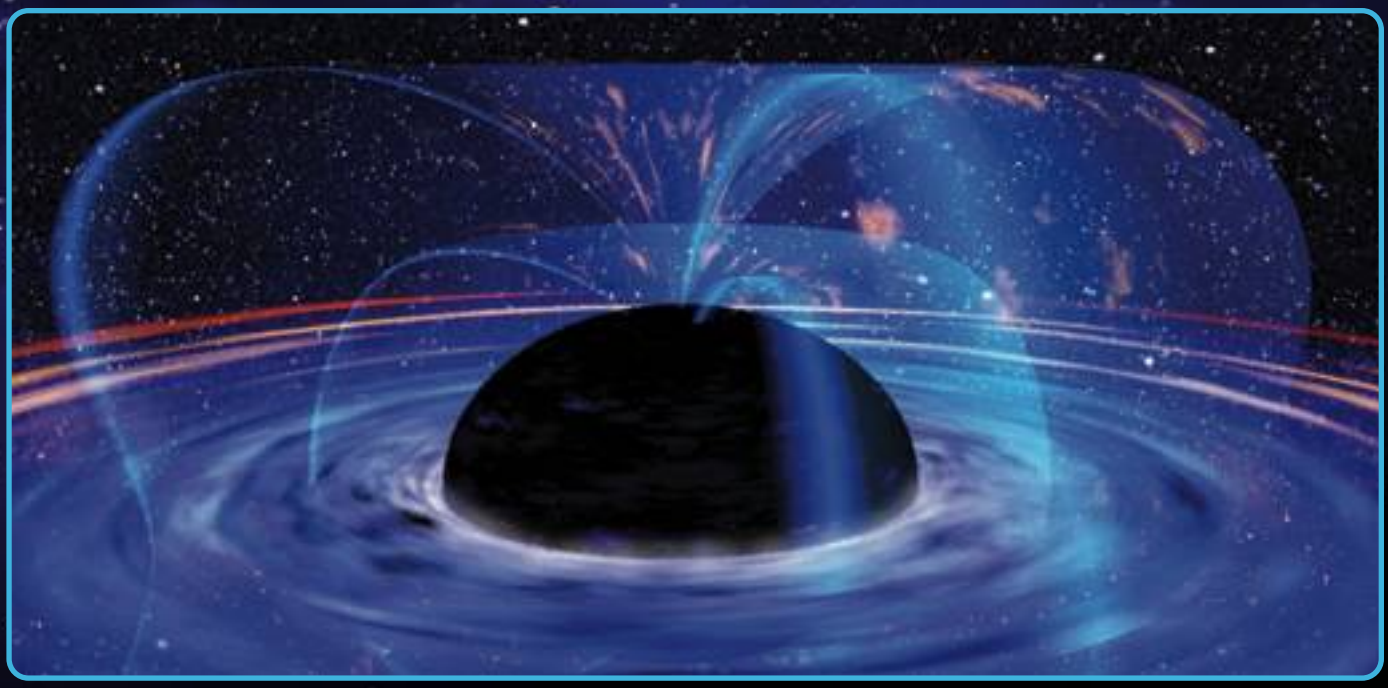
Of the known soft gamma-ray repeaters, SGR 1900+14 is probably the most interesting and possibly the most important. First discovered in 1979, it heralded its existence with three powerful gamma-ray bursts in a two-day period. These bursts let astronomers estimate its location near the center of the Milky Way, about 25,000 light-years away.

For the next 19 years, SGR 1900+14 was relatively quiet, merely glowing steadily in X rays. In late May 1998, it came alive again, bursting more than 50 times in two weeks. Then, on August 27, 1998, SGR 1900+14 released a flare so powerful it almost fried a number of space satellites. When the wave of energy from the flare swept across the night side of Earth, it ionized the outer atmosphere and affected radio communications. The accompanying X-ray pulse had so much energy that even from 25,000 light-years away, it pushed the top of the ionosphere down from an altitude of 85 miles (120 km) to 60 miles (100 km).

By carefully studying this burst, astronomers discovered buried within it an X-ray pulse repeating every 5.16 seconds. Moreover, the pulses were clearly slowing over time.

Astronomers quickly figured out that the pulses were caused by the rotation of the neutron star and its magnetic field, which was so powerful that X-ray hotspots glowed wherever the lines cut through the star's crust. As the star spun, hotspots rotated in and out of view, making it appear that the X-ray energy was pulsing. The slowdown came as the strong magnetic field robbed the star of its spin. While it will take millions of years to have much effect, the slowdown rate is far faster than normal pulsars exhibit.

The bursts occurred because the magnetar's powerful magnetic field warped the neutron star's crust. When the crust finally



ELECTROMAGNETIC FIREWORKS escape from the close vicinity of a black hole surrounded by a strong magnetic field and fed from an accretion disk built out of the remains of a companion star. Such extreme objects are proving to be common throughout the cosmos — and they are giving astrophysicists valuable insights into how the universe developed since the Big Bang. ESA/XMM-NEWTON ARTWORK

snapped from the magnetic pressure, the field and crust instantly rearranged in a kind of colossal starquake, which in turn gave out the burst of X rays and soft gamma rays.

Supermassive black holes

In the 30 years since the launch of the first space telescopes, astronomers have increasingly noticed a concentration of X-ray and gamma-ray objects toward the center of the Milky Way. Both SGR 1900+14 and GRS 1905+105 lurk in that direction. So does the Bursting Pulsar, GRO J1744+28.

All these stellar corpses, however, are tiny in comparison with the supermassive black hole — the mother of all stellar corpses — that sits at the very center of our galaxy. Dubbed Sagittarius A* (pronounced A-star), this unseen object is a gigantic cemetery of stars. It has gathered their bodies until its mass exceeds 3 million times that of the Sun.

Not only does Sagittarius A* periodically spit out X-ray bursts, its overwhelming gravitational field also draws in thousands of massive stars and several immense streams of swirling gas. In fact, some astronomers believe that recently — maybe only a few thousand years ago — a supergiant star approached too close and was ripped apart in a fiery explosion hundreds of times more powerful than the most powerful supernova.

So packed is the galactic core region that if the solar system were located there, a handful of stars would float amid the planets. In fact, without protective shielding, life as we know it simply couldn't survive within several hundred light-years of Sagittarius A* because of its high-energy emission.

Recently, a team of astronomers led by Geoffrey Bower of the University of California, Berkeley used the high resolution of the Very Long Baseline Array radio telescope to measure the size of the black hole at the heart of Sagittarius A*. They found its event horizon — the black hole's outer edge — spans some 24 million miles (39 million km), or about a hundred times the distance from Earth to the Moon.

Interestingly, Sagittarius A* is one of the smaller and more benign of the supermassive black holes known to exist. The central black holes detected in many other galaxies appear more powerful and far larger. For example, quasar 3C 273 is so energetic that its jets have flung energy and matter across distances of 300,000 to 500,000 light-years. As Herman Marshall of MIT says, "These things are stupendous!"

Truly dangerous sources

Somewhere within our galaxy lies a handful of future gamma-ray bursters. These are invisible until the moment each erupts in a beamed blast of energy so strong it is capable — even from 3,000 light-years away — of wiping out all life on Earth. Scientists blame the almost instantaneous collapse of a massive star into a black hole as the prime cause for most gamma-ray bursts. (See "In the line of fire," *Astronomy*, January 2004.)

The subsequent explosion, if close enough and aimed at us, would be so energetic as to cause a major extinction. Gamma-ray burst extinctions may have occurred already in Earth's past, for example, at the end of the Ordovician period, 440 million years ago. Luckily, such bursts are relatively rare — about 3 per million years per galaxy. Thus, the only ones we have yet to witness have exploded in other galaxies many billions of light-years away.

As astronomers look out into the night, they seek to understand the universe we were born into and consider our home. Yet we should never think of it as a safe place. Gamma-ray bursters, like the other weird high-energy objects astronomers study, remind us that nature is capricious, and we'll need all our wits and knowledge to survive.

MARTIN RATCLIFFE is the director of theaters and media services at Exploration Place in Wichita, Kansas.
RICHARD TALCOTT is a senior editor of *Astronomy* magazine.

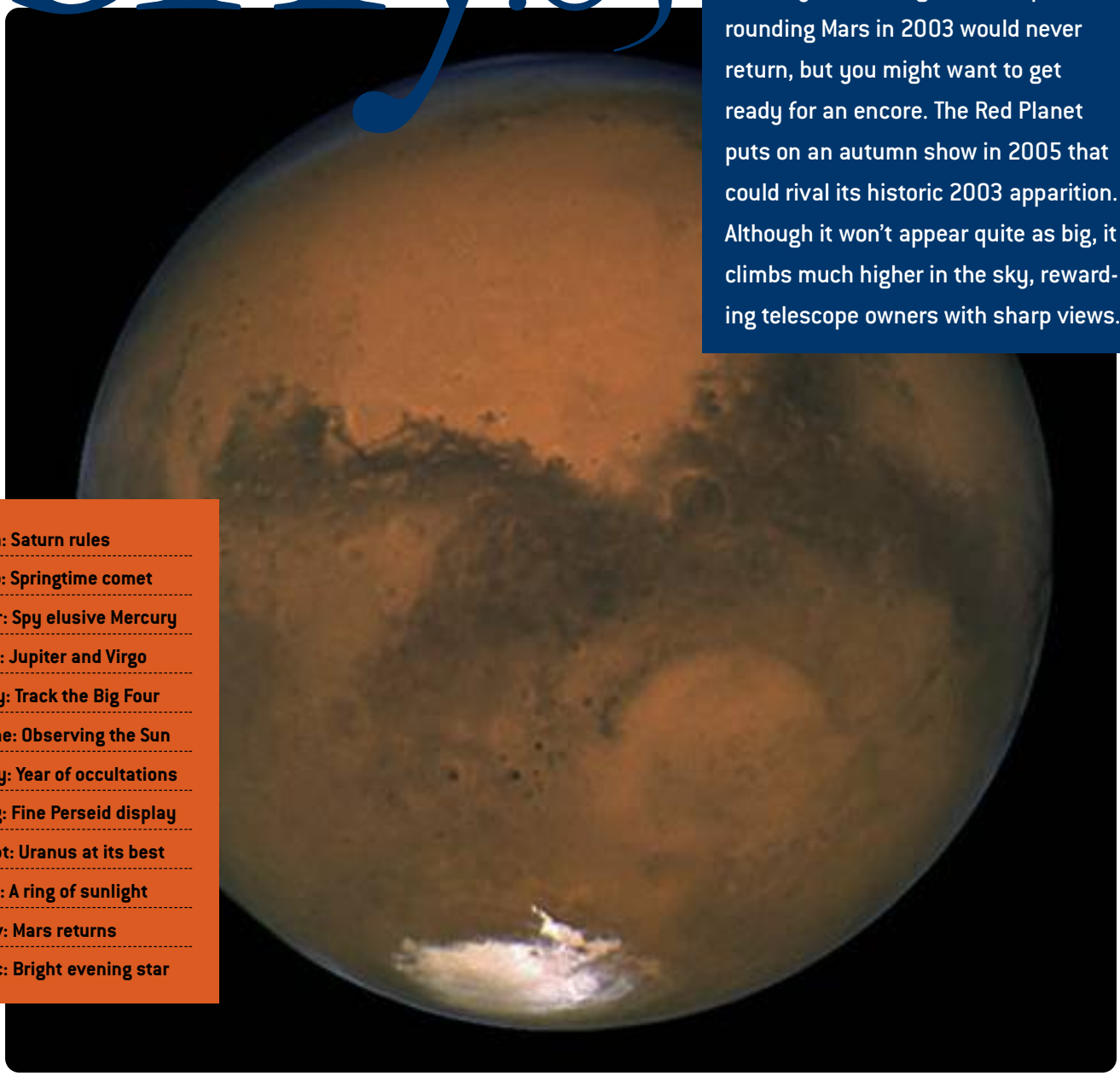
{ ETU:05 }

sky guide :05

THE RED PLANET

Mars grows big and bright again

You may have thought the hoopla surrounding Mars in 2003 would never return, but you might want to get ready for an encore. The Red Planet puts on an autumn show in 2005 that could rival its historic 2003 apparition. Although it won't appear quite as big, it climbs much higher in the sky, rewarding telescope owners with sharp views.



44 Jan: Saturn rules
46 Feb: Springtime comet
48 Mar: Spy elusive Mercury
50 Apr: Jupiter and Virgo
52 May: Track the Big Four
54 June: Observing the Sun
56 July: Year of occultations
58 Aug: Fine Perseid display
60 Sept: Uranus at its best
62 Oct: A ring of sunlight
64 Nov: Mars returns
66 Dec: Bright evening star

MARS SHINES BIG AND BRIGHT in late 2005, bringing back memories of its outstanding 2003 apparition. NASA, J. BELL (CORNELL UNIVERSITY), AND M. WOLFF (SSI)

SATURN
rules winter nights

2005

jan

Always beautiful, Saturn takes on added luster this year as the Cassini spacecraft sends back wonderful images of the planet, its rings, and its moons. And in January, the Huygens probe reaches Titan, Saturn's largest moon and the only one in the solar system with a dense atmosphere. Scientists expect spectacular results when Huygens lands on Titan's surface.

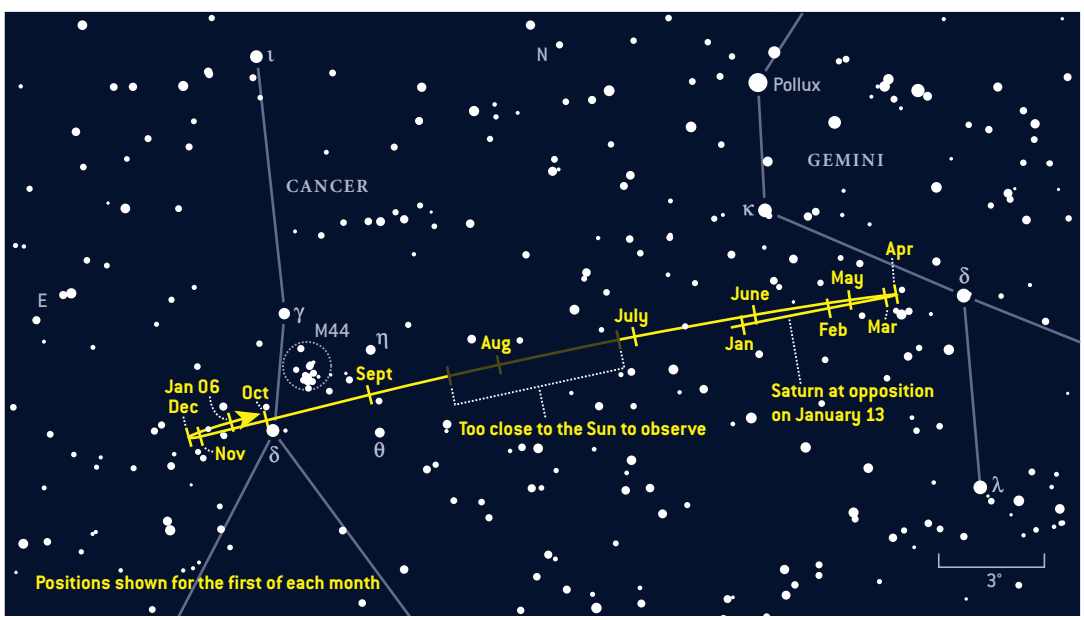
AS THE NEW YEAR OPENS, SATURN RISES IN the eastern sky as soon as the sky starts to darken. The ringed planet reaches opposition on January 13, when it lies opposite the Sun in our sky and remains visible all night. Throughout January, Saturn lies about 7° south of 1st-magnitude Pollux, the brightest star in Gemini the Twins.

Opposition also marks Saturn's closest approach to Earth of the year. About 8 astronomical units, or 750 million miles, then separate the two planets. This relative proximity means Saturn glows at its brightest, magnitude –0.4, and appears biggest, 21" across its equator. The rings, which span 47" at their widest point, more than double the planet's apparent size. Even the smallest telescope shows the rings easily. Larger scopes can spot the three main ring sections, labeled A (the outermost), B, and C (the innermost). A wide gap called the Cassini Division separates the A and B rings.

During the first third of the year, Saturn appears higher each month at sunset. By April, the planet lies due south at sunset and sets well after midnight. Saturn still sets 4 hours after the Sun in mid-May, but this evening apparition winds up by late June. Watch for the 3-day-old crescent Moon when it passes between Saturn and Pollux on June 9.

Saturn reappears before dawn in late August, when it has a brief conjunction with Mercury. On the 20th, Mercury lies 6° below the ringed planet in the eastern sky. The two stand among the stars

SATURN AND ITS RINGS will look wonderful through telescopes early this year and spectacular to the probing eyes of the Cassini spacecraft. NASA/JPL/SSI



ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

Events in red are ones you won't want to miss.

All times in the calendar are eastern time.

EST:

3 The Moon passes 0.4° south of Jupiter, 9 P.M.

Quadrantid meteor shower peaks

7 The Moon passes 3° south of Mars, 2 P.M.

The Moon passes 1.3° north of Antares, 3 P.M.

8 The Moon passes 5° south of Mercury, 9 P.M.

The Moon passes 5° south of Venus, 10 P.M.

THE FULL MOON LOOKS about 13-percent larger in August (right) than it does in January, thanks to its changing distance. FROM THE CONSOLIDATED LUNAR ATLAS (LPL/UA)

of Cancer the Crab. By early September, you can spot Saturn near the Beehive star cluster (M44). On the 16th, the planet passes less than a degree south of the cluster — a magnificent sight through binoculars. Saturn will return to the vicinity of M44 for its next opposition in January 2006.

The Moon from afar

This month's Full Moon will be on the small side. Perhaps not conspicuously so, but it is smaller than normal nonetheless. This happens because the Full Moon of January 25 lies 251,987 miles away from Earth, compared with its average distance of 238,860 miles. It spans 29.5', some 1.6' less than average. Later in the year, on August 19, the Full Moon will be closer than average, just 222,232 miles away from Earth. This results in a larger diameter of 33.4'.

With some planning and good luck with clear skies, you can try a fun experiment. Take a photograph of the Full Moon in January using a telephoto lens. Then, come August, use the same lens and take another photograph of the Full Moon. Make a print of each, or divide your digital image in half, and join the two halves of the Moon. The 13-percent difference in their apparent sizes should be obvious. This experiment will work only if you use the identical lens for both pictures.

Why does this happen? Like all celestial bodies, the Moon doesn't orbit Earth in a perfect circle, but instead, in an ellipse. As Earth orbits the Sun, this ellipse stays at a nearly fixed orientation relative to the stars for each year. One point along the Moon's orbit lies closest to Earth, a point called perigee. At the opposite side of its orbit, the Moon lies farthest from Earth, a point called apogee.

The Moon passes through both points every month. However, a Full Moon occurs near one of these points only twice a year. The same goes for any other phase. Because the lunar orbit is nearly fixed in space, this orientation results in perigee or apogee being in line with the Sun and Earth, and thus coincident with a Full or New Moon, only twice per year.

11 The Moon passes 5° south of Neptune, 6 P.M.

13 The Moon passes 4° south of Uranus, 3 A.M.

13 Saturn is at opposition, 6 P.M.

Mercury passes 0.3° south of Venus, 8 P.M.

24 The Moon passes 5° north of Saturn, 3 A.M.

31 The Moon passes 0.9° south of Jupiter, 6 A.M.

S	M	T	W	T	F	S
						1
2	◐	4	5	6	7	8
9	○	11	12	13	14	15
16	◑	18	19	20	21	22
23	24	●	26	27	28	29
30	31					

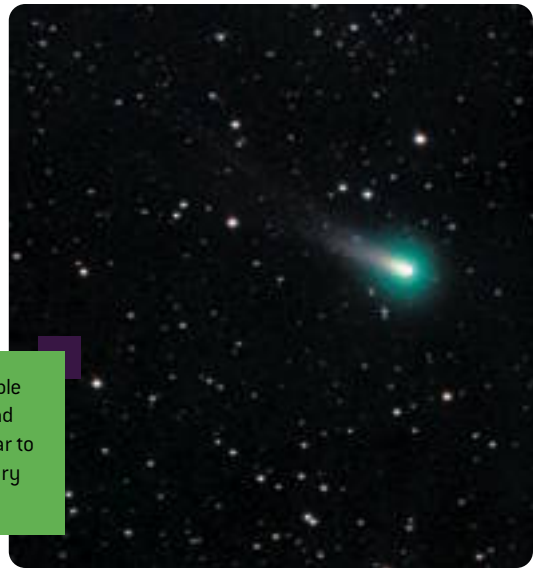
2005

feb

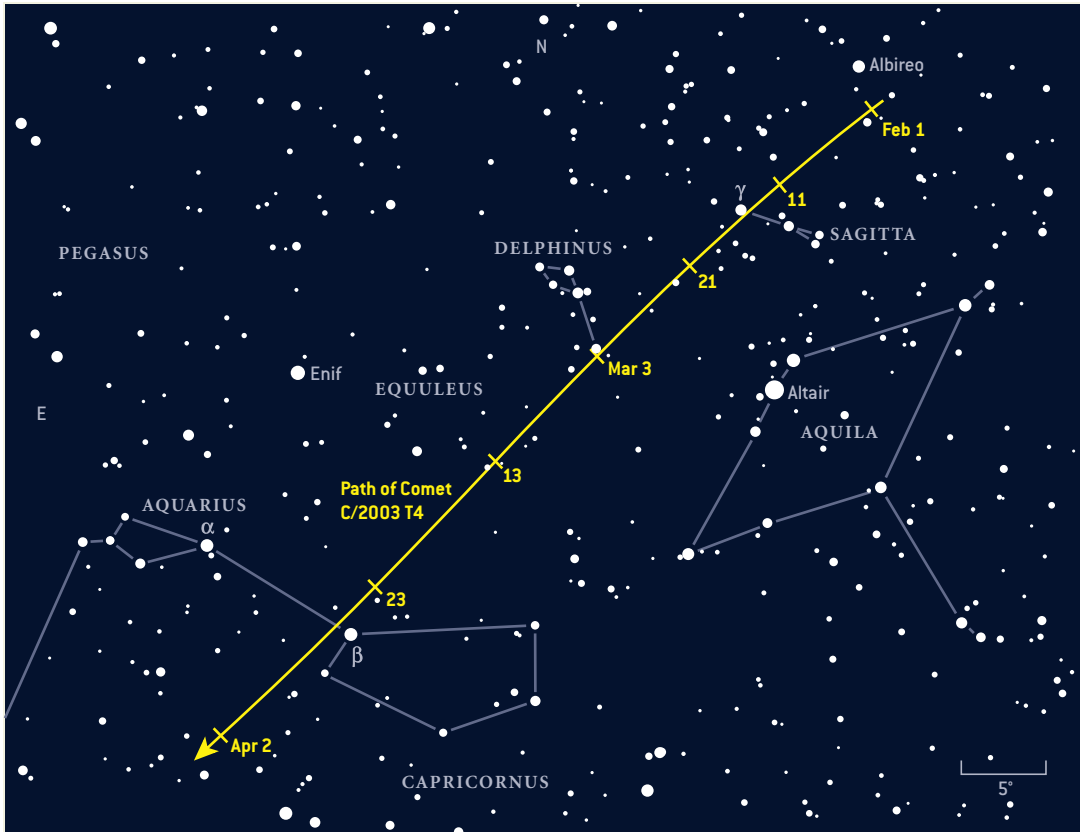
Yet another SPRINGTIME COMET

FOR SOME REASON, BRIGHT COMETS SEEM to have an affinity for spring. Last year, comets C/2001 Q4 (NEAT) and C/2002 T7 (LINEAR) put on good shows. And no one who was around in the late 1990s can forget Comet Hyakutake and Comet Hale-Bopp, both springtime wonders.

This year sees another comet that could reach naked-eye visibility during the spring. Astronomers expect C/2003 T4 (LINEAR) to brighten to around 7th magnitude in February and possibly reach 6th magnitude in March and April. Throughout this period, the comet is visible in the eastern sky before dawn. But as it moves fairly rapidly to the south



COMET C/2003 T4 may be visible to the naked eye this winter and spring. If so, it could look similar to C/2002 T7, seen here in February 2004. GERALD RHEMANN AND MICHAEL JÄGER



Several comets grace the sky this year. Comet C/2003 T4 (LINEAR) likely will be the best — perhaps glowing bright enough to see with the naked eye in late winter and early spring. But the most intriguing should be Comet 9P/Tempel 1, which receives a visit from the Deep Impact probe in July. (See page 28 for details on the comet and the spacecraft.)

EST:

3 Neptune is in conjunction with the Sun, 2 P.M.

The Moon passes 1.1° north of Antares, midnight

5 The Moon passes 4° south of Mars, 8 A.M.

14 Mercury is in superior conjunction, 6 A.M.

14 Venus passes 1.0° south of Neptune, 2 P.M.

20 The Moon passes 5° north of Saturn, 6 A.M.

25 Uranus is in conjunction with the Sun, 2 A.M.

27 The Moon passes 1.2° south of Jupiter, 10 A.M.

and east, its altitude in the morning sky will decrease noticeably from week to week.

The comet begins February within 3° of the lovely double star Albireo (Beta [β] Cygni), the star that forms the head of Cygnus the Swan. It then glides through Vulpecula and Sagitta in February and Delphinus and Equuleus in the first half of March. From late March until it disappears from view in mid-April, C/2003 T4 traverses Aquarius.

To locate C/2003 T4, use the map at lower left to find the correct region. Then, search for a fuzzy blob with your binoculars. If the comet brightens as much as astronomers expect, you might see it with your naked eyes from a dark site. Its tail will point straight up from the horizon.

The comet's fuzzy appearance stems from its physical nature. When located far from the Sun, a comet exists as a cold, inert mixture of ice and dust. As the comet nears the Sun, however, its nucleus warms and the ices start to turn directly into gas, releasing trapped dust in the process. The expanding cloud of gas and dust forms the "coma," which can span 100,000 miles or more and gives the comet its fuzzy appearance. The solar wind and pressure from sunlight push the gas and dust away from the comet, forming two tails.

Explore the winter sky

Winter finds the Big Dipper climbing in the northeast, with the three stars of its handle pointing to the horizon and the four stars of its bowl above them. The entire sky rotates around Polaris, a 2nd-magnitude star found by extending a line from the upper pair of bowl stars to the left of the Dipper.

Turn around, with your back to the Dipper, and you'll be facing the diamond-studded winter sky. Orion the Hunter is central to the brilliant scene. Three closely spaced 2nd-magnitude stars form a straight line that represents Orion's unmistakable "belt." Extending the imaginary line joining these stars to the upper right leads to Taurus the Bull and its ruddy 1st-magnitude star, Aldebaran. Reverse the direction of your gaze to the belt's lower left and you cannot miss Sirius — the brightest star in the heavens at magnitude –1.5.

Now, move perpendicular to the belt from its westernmost star and find the red supergiant star Betelgeuse at one of Orion's shoulders. Continuing this line brings you to a pair of bright stars, Castor and Pollux, in Gemini the Twins. Head south of the belt, instead, and your gaze will fall on the blue supergiant star Rigel, Orion's other luminary.

Above Orion is brilliant Capella in Auriga. Extending a line through Orion's shoulders to the east leads to Procyon in Canis Minor. Once you have these main stars mastered, you can use the chart to discover fainter constellations. Before leaving Orion, however, aim your binoculars at the line of stars below the belt. The fuzzy "star" in the middle is the grand Orion Nebula (M42), a stellar nursery illuminated by bright, newly formed stars.

S	M	T	W	T	F	S
		1	◐	3	4	5
6	7	○	9	10	11	12
13	14	◑	16	17	18	19
20	21	22	●	24	25	26
27	28					

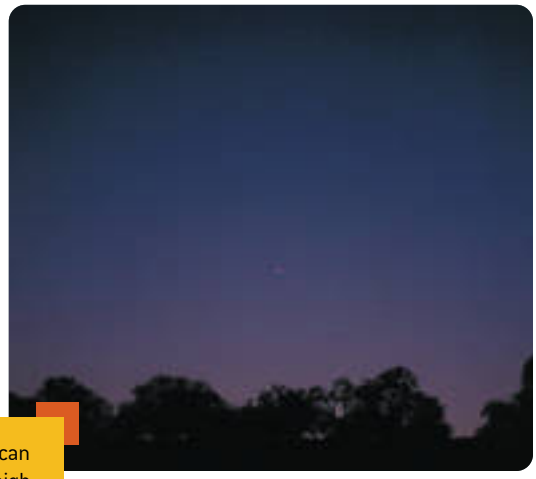
2005 may

Spying the ELUSIVE MERCURY

Tradition holds that Copernicus — the man who placed the Sun at the center of the solar system and one of the greatest astronomers of all time — never glimpsed Mercury. You don't have to be so unlucky. This year provides several chances to see the innermost planet against the twilight glow, if you know when and where to search for it.

MERCURY'S TIGHT ORBIT AROUND THE SUN results in only a handful of viewing opportunities each year. The tiny planet lies 57 million miles closer to the Sun than Earth. Consequently, as viewed from our planet, the breadth of Mercury's orbit spans just 27° on either side of the Sun, relegating it to almost constant twilight. That means Mercury must be observed low in the west shortly after sunset or low in the east just before dawn.

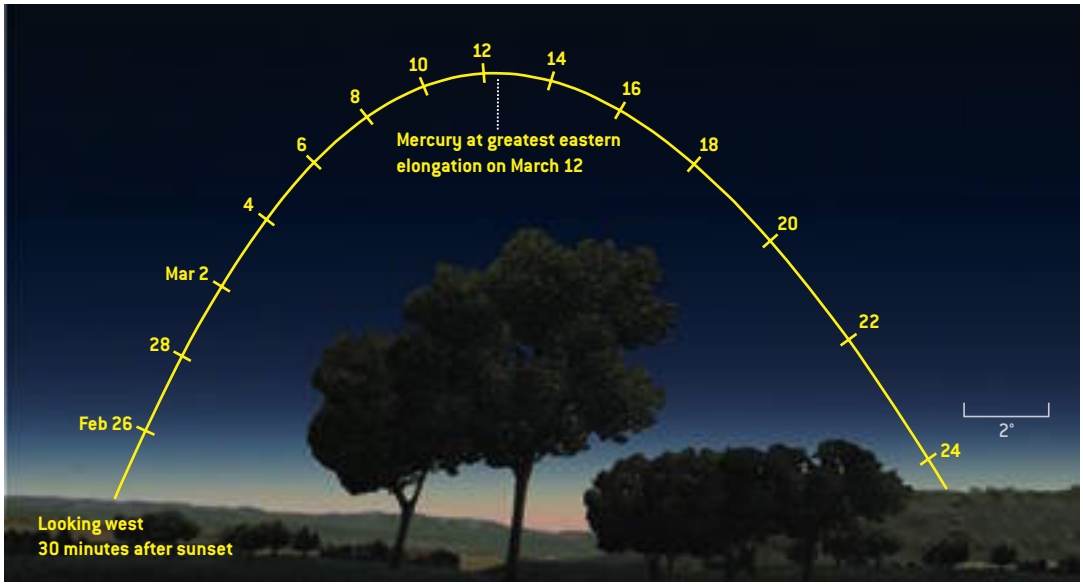
This year provides three evening and four morning opportunities to view Mercury. For observers in the Northern Hemisphere, the best evening apparition comes between February 25 and March 23, when Mercury lies highest in the sky. The most favorable morning appearance lasts from November 30 to December 31. However, Mercury climbs high enough to be viewed during three other periods this year.



NORMALLY ELUSIVE MERCURY can be seen easily when it climbs high enough, as it will during March evenings this year. GEORGE LIVADARAS

The first several mornings of 2005 offer good chances to see Mercury, thanks to the proximity of the much brighter Venus. The first dawn of the year finds Mercury 1° above its companion. Venus shines about twenty-five times brighter than Mercury (magnitude –3.9 vs. –0.3), so use it as a guide to the elusive planet. Both planets display gibbous disks through a telescope, with Venus's appearing fatter.

For the next two weeks, the two remain close enough to view them in the same low-power eyepiece, although their relative positions shift a bit. During the second week of January, Mercury slides to the right of Venus. By the 13th, Mercury lies



EST:

- 3 The Moon passes 0.8° north of Antares, 6 A.M.
- 6 The Moon passes 5° south of Mars, 1 A.M.
- 7 The Moon passes 5° south of Neptune, 7 P.M.
- 11 The Moon passes 3° south of Mercury, 11 A.M.
- 12 Mercury is at greatest eastern elongation (18°), 1 P.M.
- 19 The Moon passes 5° north of Saturn, 11 A.M.
- 20 Equinox (northern spring/southern autumn begins), 8 A.M.
- 23 Asteroid Pallas is at opposition, 2 A.M.

0.3° south of Venus. Within the next several days, Mercury sinks into the Sun's glow and out of sight.

The best evening views of Mercury this year start in late February and improve rapidly heading into March. The planet's altitude increases by almost 1° per day. Mercury lies 4° (8 Moon-widths) to the lower right of a slim crescent Moon on March 11 and sets 90 minutes after the Sun. The following night, Mercury reaches its greatest elongation east of the Sun (18°) and stands 11° above the horizon half an hour after sunset.

Through a telescope, Mercury presents a disappointingly small 7"-diameter disk that appears half-lit. Following greatest elongation, the planet quickly dips back toward the horizon, becoming lost in the twilight within about ten days.

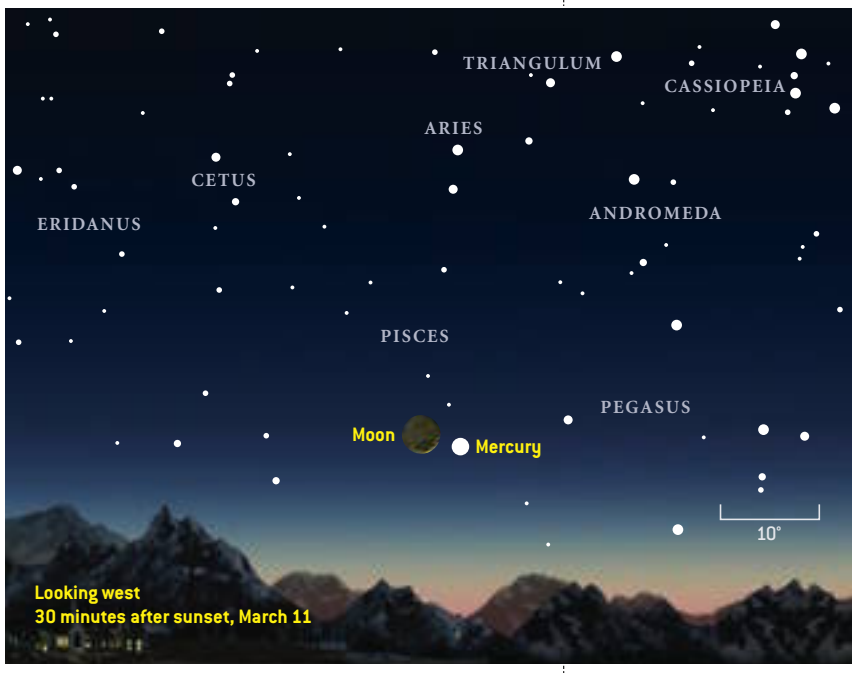
The second-best morning apparition occurs in August and finds Mercury near Saturn. Don't confuse the two planets around August 21, when they both shine at magnitude 0.3. Saturn rises 30 minutes earlier and appears higher in the predawn sky.

Mercury rises a few minutes earlier each morning and grows brighter as well. By the 23rd, it lies 18° west of the Sun, its greatest elongation for this apparition. Mercury falls back toward the twilight glow after the 23rd, although it remains easy to see for a short period as it continues to brighten.

The best morning apparition of the year occurs in December. You can try spotting Mercury on November 30, when it lies 6° to the upper left of a very old and very thin crescent Moon. (The Moon is just 27 hours from its new phase.) They rise together an hour before the Sun. You'll need a clear sky and unobstructed horizon toward the east-southeast to spot them in the brightening sky. Binoculars will help a lot.

A week later, Mercury should prove to be an easy object. By then, it has brightened to magnitude –0.1 and stands 7° above the horizon a full hour before sunrise. Jupiter then appears about 15° to the upper right of Mercury. The innermost planet reaches greatest western elongation on December 12, when it lies 21° from the Sun.

On December 15, Mercury passes 1° north of the double star Beta (β) Scorpii. Five days later, it lies 6° north of ruddy, 1st-magnitude Antares. Mercury then shines at magnitude –0.5, easily outshining the brightest star in Scorpius. The planet remains visible through the end of 2005, although it sinks ever deeper into the gathering dawn. Look for it again on the 29th, when a very slim crescent Moon returns to the scene 7° to the right of Mercury.



/// WHEN TO SEE MERCURY IN 2005

EVENING

Greatest elongation	*Visible from*	*Peak altitude*
March 12	February 25 to March 23	11°
July 8	June 11 to July 30	10°
November 3	September 30 to November 19	4°

MORNING

Greatest elongation	*Visible from*	*Peak altitude*
April 26	April 6 to May 27	4°
August 23	August 13 to September 9	11°
December 12	November 30 to December 31	12°

26 The Moon passes 1.0° south of Jupiter, 11 A.M.

29 Mercury is in inferior conjunction, 11 A.M.

30 The Moon passes 0.7° north of Antares, noon

Venus is in superior conjunction, 10 P.M.

S	M	T	W	T	F	S
		1	2	◐	4	5
6	7	8	9	○	11	12
13	14	15	16	◑	18	19
20	21	22	23	24	●	26
27	28	29	30	31		

2005 apr

THE KING and the Maiden

Giant Jupiter shines at its brightest and appears at its biggest through a telescope when it reaches opposition in early April. Because it will slide southward during the next several years, observers in the Northern Hemisphere will have to view it through thicker layers of air. Jupiter won't be as well placed again until 2010.

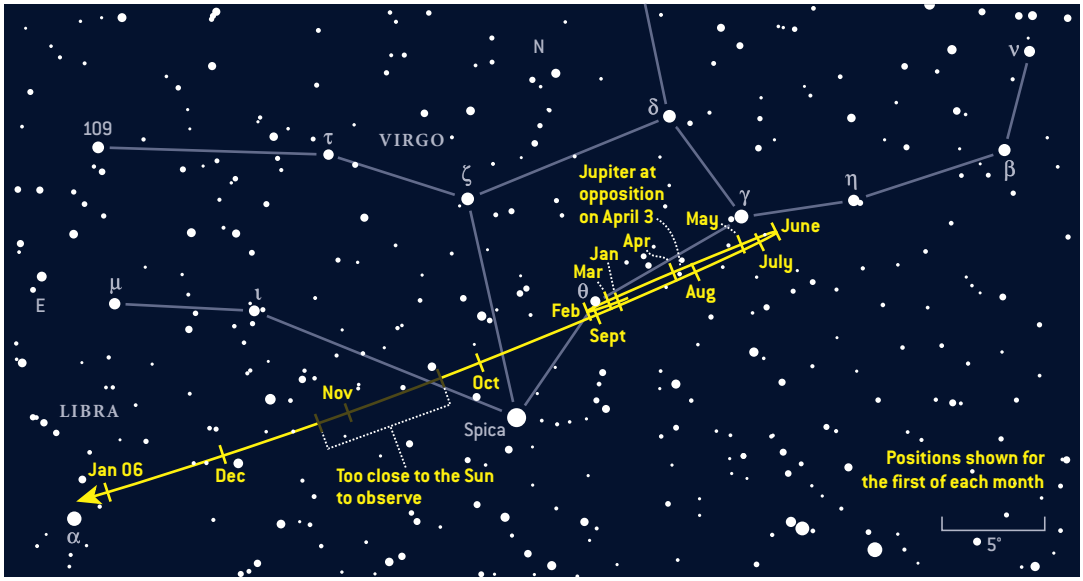
JUPITER REACHES OPPOSITION ON APRIL 3, the peak of its 12-month-long apparition. This places the giant planet on view throughout spring, as temperatures grow more comfortable. Jupiter spends the first quarter of the year in the morning sky. On January 1, it rises in the east at 1 A.M. local time. You'll find it 7° northwest of 1st-magnitude Spica, the brightest star in Virgo the Maiden.

From January until opposition in April, Jupiter's apparent size grows from 36" to 44". During the same period, the planet brightens from magnitude –2.0 to –2.5. Jupiter's brilliance makes it easy to identify — it outshines every other object in the region except the Moon when it passes by. The planet edges closer to Spica during January and then reverses direction, sliding slowly closer to Porrima (Gamma [γ] Virginis). At opposition, when Jupiter rises at sunset, it stands 10° northwest of Spica.

JUPITER DOMINATES the night throughout April, shining brighter than any other point of light in the sky. NASA/JPL/SSI

Jupiter remains in Virgo throughout this apparition, which runs through September. Just before it disappears from view, Jupiter has a dazzling conjunction with Venus. The two approach within 1.2° on September 1, with Venus appearing some eight times brighter. Jupiter swings behind the Sun in October, reappearing in the morning sky in early November, when it lies 10° east of Spica. By the end of the year, the planet rises around 3 A.M. local time and has moved into Libra.

Any telescope will show significant features in Jupiter's atmosphere. Most obvious are the two



EDT:

3 Jupiter is at opposition, noon

The Moon passes 4° south of Mars, 6 P.M.

4 The Moon passes 5° south of Neptune, 5 A.M.

5 The Moon passes 3° south of Uranus, 6 P.M.

7 The Moon passes 3° south of Mercury, 10 A.M.

8 Annular/total solar eclipse, 5 P.M.

12 Mars passes 1.2° south of Neptune, 8 P.M.

15 The Moon passes 5° north of Saturn, 9 P.M.

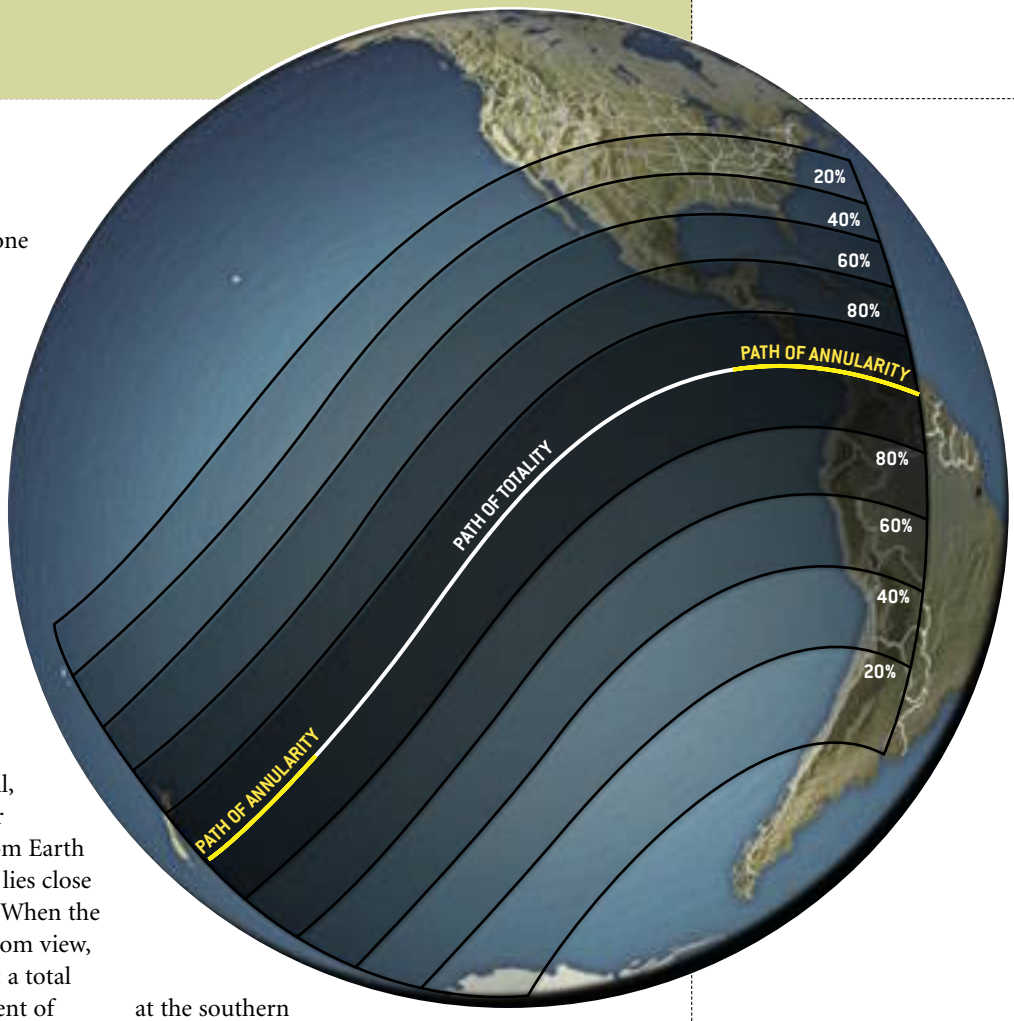
parallel dark belts that circle the planet, one on either side of the equator. Although scores of features can be seen in the jovian atmosphere, they remain subtle. The famed Great Red Spot no longer shows the ruddy hue of years past but appears a rather soft salmon-pink.

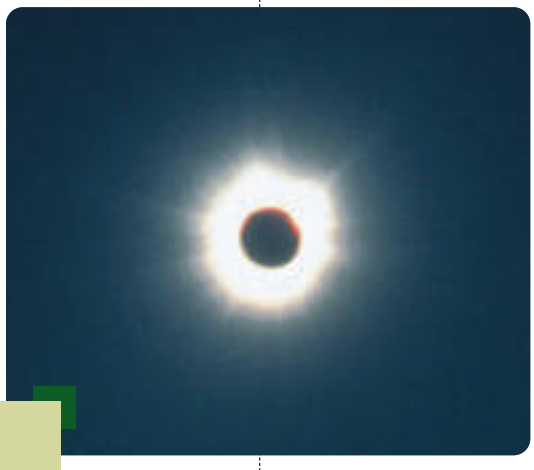
A hybrid eclipse

After an absence of 18 years, the rarest type of solar eclipse returns to Earth on April 8. Approximately 35 percent of all solar eclipses are partial, where the Moon blocks only part of the Sun's disk from view. Another 32 percent are annular eclipses, in which the Moon crosses the center of the Sun's disk but doesn't appear large enough to cover it all, leaving a ring of sunlight visible. Annular eclipses occur when the Moon lies far from Earth and thus appears small, or when the Sun lies close to Earth and thus appears large, or both. When the Moon hides all of the Sun's bright disk from view, we see the most spectacular eclipse of all: a total eclipse. This variety accounts for 28 percent of all solar eclipses.

Add up those percentages, and you'll find a deficit of 5 percent. That represents a hybrid eclipse: total over part of the path and annular over the rest. This happens when the distances to the Sun and Moon balance precariously at the crossover point between a total and annular eclipse. On the section of the eclipse track near local noon, Earth lies close enough to the Moon that the eclipse appears total. At the ends of the track, around sunrise and sunset, Earth lies slightly farther from the Moon and our satellite doesn't cover all of the Sun.

The April 8 event cuts a narrow swath from east of New Zealand to northern South America. Totality reaches a maximum of 42 seconds in the middle of the South Pacific. The longest period of annularity occurs in Peru and lasts 34 seconds. A partial eclipse can be seen from western South America and southern North America. Observers at the southern tip of Florida will see about half the Sun blocked from view. Those in Texas and much of the southeastern United States will see a quarter of the Sun disappear. And those in the eastern and south-central states will witness at least a small bite taken from the Sun. As always, any time you observe the Sun outside totality, use proper eye protection.





FORTY SECONDS OF TOTALITY await those observers intrepid enough to journey to the South Pacific on April 8. JERRY SCHAD

22 Lyrid meteor shower peaks

The Moon passes 0.6° south of Jupiter, 2 P.M.

26 Mercury is at greatest western elongation (27°), 1 P.M.

The Moon passes 0.7° north of Antares, 7 P.M.

S	M	T	W	T	F	S
					◐	2
3	4	5	6	7	○	9
10	11	12	13	14	15	◑
17	18	19	20	21	22	23
●	25	26	27	28	29	30

Track down

2005 may

THE BIG FOUR

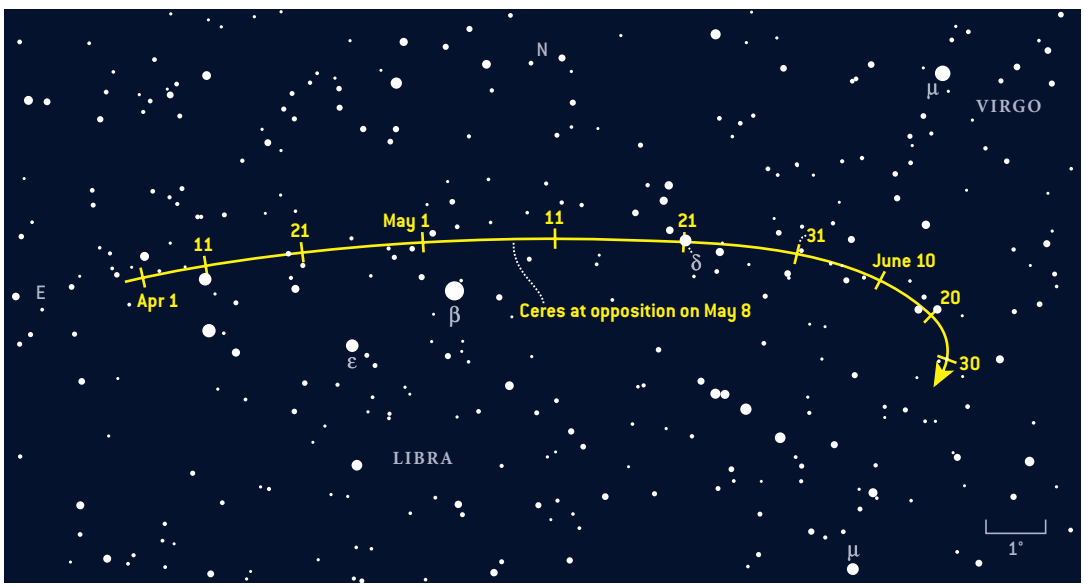
ONCE DUBBED THE "VERMIN OF THE SKY," asteroids constitute the largest number of known objects in the solar system. Most lie between the orbits of Mars and Jupiter and prove hard to find, but the brightest can be glimpsed with binoculars.

The four brightest asteroids — Ceres, Pallas, Juno, and Vesta — were discovered in the first decade of the 19th century. Since then, tens of thousands of asteroids have been found, but the initial quartet remains known as the Big Four. All but Vesta reach opposition this year, and Vesta brightens to 6th magnitude in December. Why not challenge yourself to spot all four?

Ceres reaches opposition on May 8 in Libra. Glowing at 7th magnitude, it's an easy object to see in binoculars. In early May, Ceres passes 1° north of Beta (β) Librae. And on May 18, it passes 0.3° north of Delta (δ) Librae. You'll be able to see the motion of Ceres over the course of an hour.

Pallas reaches opposition on March 23 in Virgo. On March 30, it lies just 0.5° east of M87, one of the brightest members of the

ASTEROID CERES glows bright enough to pick up easily through binoculars. You can confirm its identity by watching for its telltale motion from night to night. K. BOLAM



Italian monk Giuseppe Piazzi discovered the first asteroid, later named Ceres, on January 1, 1801. Three more followed in the next 6 years, and these four remain the easiest asteroids for backyard observers to see. Ceres puts on the best show this year, but Pallas, Juno, and Vesta also glow bright enough to be seen with binoculars or a small scope.

EDT:

1 The Moon passes 5° south of Neptune, 11 A.M.

2 The Moon passes 3° south of Mars, 11 A.M.

3 The Moon passes 3° south of Uranus, 2 A.M.

5 Eta Aquarid meteor shower peaks

6 The Moon passes 3° north of Mercury, 6 A.M.

8 Asteroid Ceres is at opposition, 2 P.M.

13 The Moon passes 5° north of Saturn, 9 A.M.

14 Mars passes 1.2° south of Uranus, 4 P.M.

Virgo cluster of galaxies. The asteroid glows at 7th magnitude during the month, an easy target for binoculars, although seeing the galaxy requires a telescope.

Eighth-magnitude Juno comes to opposition on December 9, when it lies northwest of the Orion Nebula (M42). Vesta reaches opposition in the first week of 2006 but becomes an easy binocular target in Gemini during the final months of 2005. On December 23, the 6th-magnitude asteroid lies just 0.2° west of Wasat (Delta Geminorum).

Explore the spring sky

The Big Dipper, our signpost in the sky, swings overhead during spring and lies near the center of the chart. Follow the arc of stars outlining the Dipper's handle away from the bowl and you will land on brilliant Arcturus. This orangish star dominates the spring sky in the kite-shaped constellation Boötes the Herdsman. Well to the west of Boötes lies Leo the Lion. You can find its brightest star, Regulus, by using the pointers of the Dipper in reverse. Regulus lies at the base of a group of stars shaped like a sickle, which represents the lion's head.

Midway between Regulus and Pollux in Gemini, which now is sinking in the west, is the diminutive group Cancer the Crab. Centered in this group is a hazy patch of light that binoculars reveal as the Beehive star cluster (M44). To the southeast of Leo lies the realm of the galaxies and the constellation Virgo the Maiden.

Virgo's brightest star, Spica, shines at magnitude 1.0. In the direction of Virgo and its neighbors, Leo, Coma Berenices, and Ursa Major, lie thousands of galaxies whose light is unhindered by intervening dust in our own galaxy. However, all these galaxies are elusive to the untrained eye and require binoculars or a telescope to be seen.

Midway between Arcturus and Vega, the bright "summer" star rising in the northeast, lies a semicircle of stars representing Corona Borealis the Northern Crown and a large region that houses Hercules the Strongman. It's here we find the northern sky's brightest globular star cluster, M13.

Returning to Ursa Major, check the second-to-last star in the Dipper's handle. Most people see it as a double, while binoculars show this easily. The two are called Mizar and Alcor, and they lie 0.2° apart. A telescope reveals Mizar itself to be a double. Its companion star lies just 14" away.

/// WHEN TO SEE ASTEROIDS IN 2005

ASTEROID	OPPOSITION	CONSTELLATION	MAGNITUDE
1 Ceres	May 8	Libra	7.0
2 Pallas	March 23	Virgo	7.1
3 Juno	December 9	Orion	7.5
7 Iris	June 3	Ophiuchus	9.2
8 Flora	January 14	Gemini	8.4
532 Herculina	January 16	Gemini	8.9

19 The Moon passes 0.4° south of Jupiter, 6 P.M.

24 The Moon passes 0.8° north of Antares, 4 A.M.

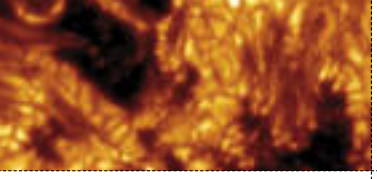
28 The Moon passes 5° south of Neptune, 5 P.M.

30 The Moon passes 3° south of Uranus, 8 A.M.

31 Saturn passes 7° south of Pollux, 1 A.M.

The Moon passes 0.5° south of Mars, 5 A.M.

S	M	T	W	T	F	S
◐	2	3	4	5	6	7
○	9	10	11	12	13	14
15	◑	17	18	19	20	21
22	●	24	25	26	27	28
29	◑	31				



Observing THE SUN

2005 June

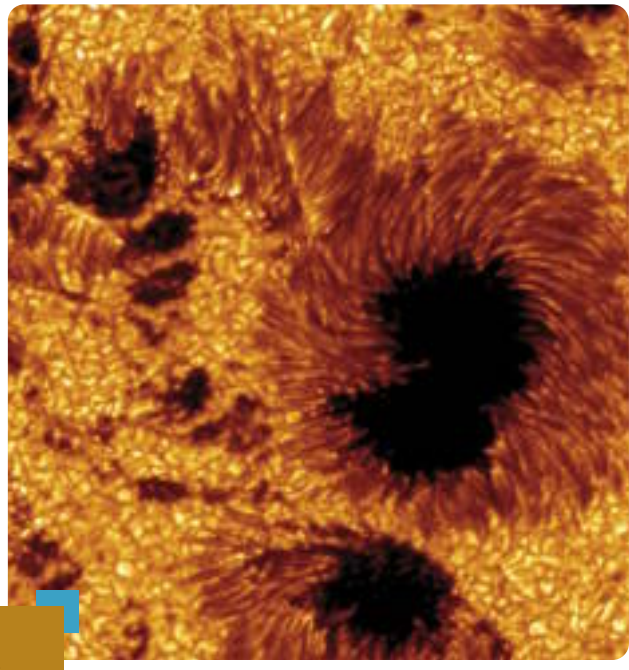
The Sun is the only celestial object whose effects can be seen both day and night. During daylight hours, our star provides a wealth of detail — most notably sunspots — to observers who take the precautions necessary to protect their eyesight. At night, the glow of an aurora is the visible manifestation of solar particles striking the atmosphere.

ONE OF THE MOST FASCINATING OBJECTS visible to backyard observers remains one of the least observed. Few people even think to view the Sun because it doesn't come out at night. Yet as the nearest star to Earth, the Sun is the only one that shows any detail. Just be sure to protect your eyesight by taking safety precautions.

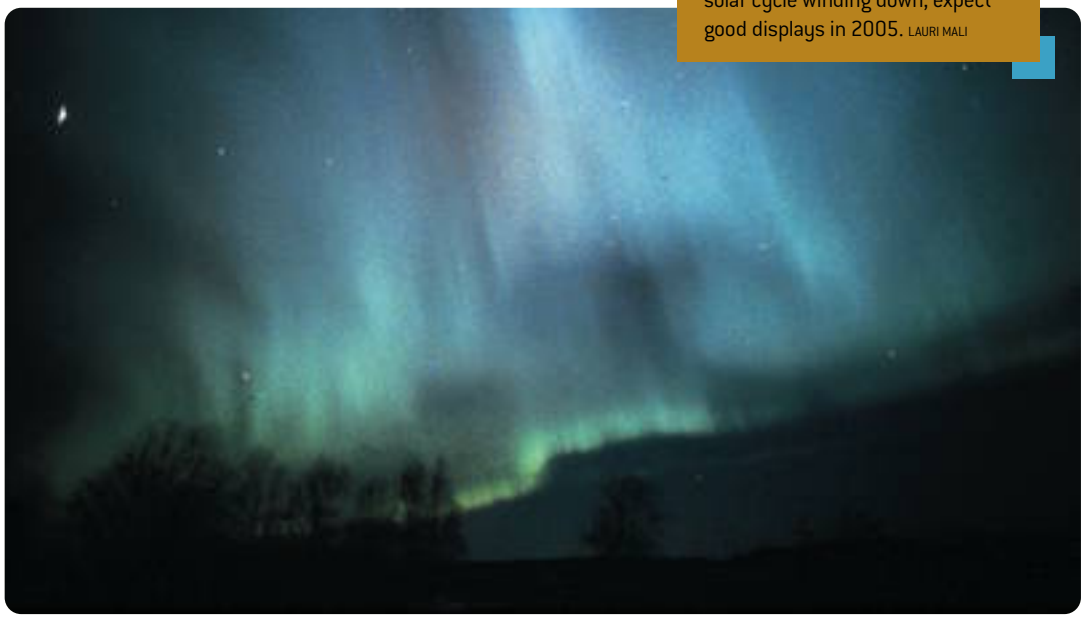
The easiest way to view the Sun is to project its image onto a white card. Point the telescope by minimizing the scope's shadow on the card. Never put your eye near the eyepiece. The back of the eye has no pain receptors, so blindness can result without you knowing it. Alternatively, place a good solar filter over the front end of your scope.

The most obvious features on the Sun are sunspots. Individual spots or groups of spots that belong to active regions can change shape from day to day. Some become huge, reaching many times the diameter of Earth.

One aspect of solar activity can be seen at night. Charged particles from the Sun rain



SUNSPOTS ARE EASY TO TRACK during their 2-week trek across the Sun's face. Look for their dark umbras and lighter penumbras. ROYAL SWEDISH ACADEMY OF SCIENCES



GLOWING AURORAE, sparked by solar activity, often dazzle visitors to northern latitudes. Even with the solar cycle winding down, expect good displays in 2005. LAURI MALI

EDT:

3 Mercury is in superior conjunction, 5 A.M.

8 The Moon passes 4° north of Venus, 8 A.M.

9 The Moon passes 5° north of Saturn, 10 P.M.

13 Pluto is at opposition, 11 P.M.

16 The Moon passes 0.4° south of Jupiter, 3 A.M.

20 The Moon passes 0.7° north of Antares, 2 P.M.

21 Solstice (northern summer/southern winter begins), 3 A.M.

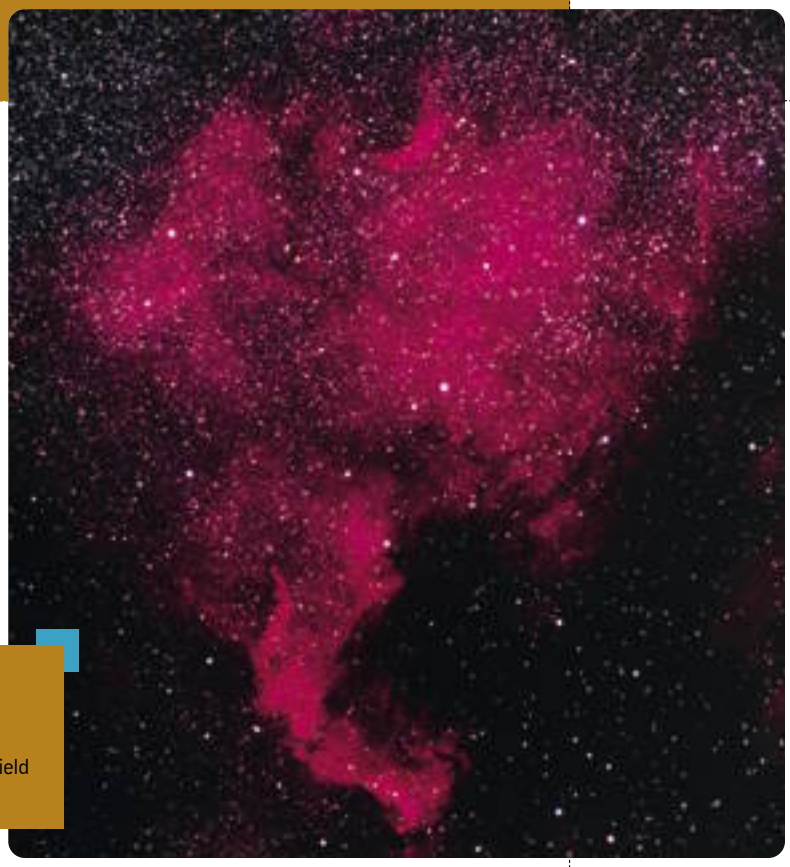
23 Venus passes 5° south of Pollux, 8 A.M.

down on Earth's polar regions, where they excite molecules in the atmosphere and cause them to emit light. These glowing aurorae, or northern lights, have fascinated people for centuries.

The Sun now is entering a quieter stage of activity in its 11-year cycle. Sunspots will cluster closer to the Sun's equator this year, and their number should decline slowly. Aurorae should be visible less frequently at southern latitudes.

Beautiful as a swan

Summer provides the best opportunity to see the wonders of the Milky Way. While the riches of Sagittarius and Scorpius lurk near the southern horizon, Cygnus the Swan passes nearly overhead. The Swan's bright stars, gleaming star clusters, and bright emission nebulae make it a favorite of backyard observers.

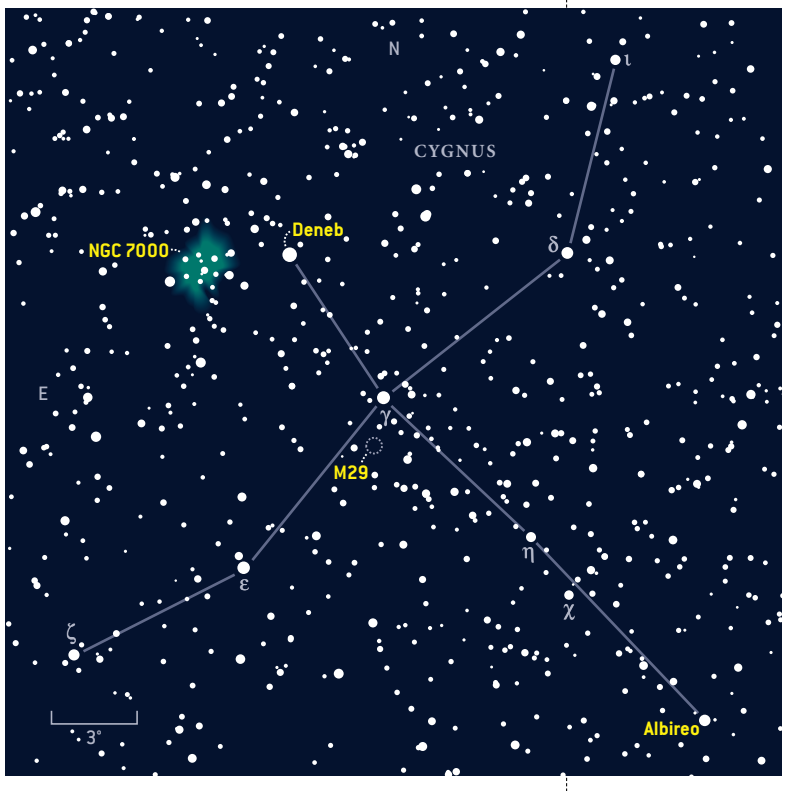


THE NORTH AMERICA NEBULA stands just 3° east of Deneb, where it impresses observers armed with binoculars or rich-field telescopes. W. A. TREMBLY, JR.

The stars at the two ends of the Swan's body are particularly noteworthy. The tail star, Deneb, shines brightly at magnitude 1.3 despite a distance of some 1,600 light-years. To appear so bright, it must give off 70,000 times as much light as the Sun, making it one of the most luminous stars in the sky. At the other end of the Swan lies Albireo, which many observers consider the finest double star. The contrast between the orange and blue components makes it a target you shouldn't miss.

Perhaps the best star cluster in Cygnus is M29. You can find it 2° south of Gamma (γ) Cygni, the star at the center of the Northern Cross. Small telescopes do the best job of isolating this cluster from the richness of the surrounding star fields.

The most-observed gas cloud in Cygnus has to be the North America Nebula (NGC 7000), located 3° east of Deneb. Some people have spotted the nebula with their naked eyes under a very dark sky. The best views come through binoculars and rich-field telescopes, which can show the nebula's entire 2° span in one field of view.



24 The Moon passes 5° south of Neptune, midnight

25 Venus passes 1.3° north of Saturn, 5 P.M.

26 Mercury passes 1.4° north of Saturn, 2 A.M.

The Moon passes 3° south of Uranus, 3 P.M.

27 Mercury passes 0.08° south of Venus, 5 P.M.

28 The Moon passes 2° north of Mars, midnight

S	M	T	W	T	F	S
			1	2	3	4
5	○	7	8	9	10	11
12	13	◑	15	16	17	18
19	20	21	●	23	24	25
26	27	◐	29	30		

2005 July

A year of OCCULTATIONS

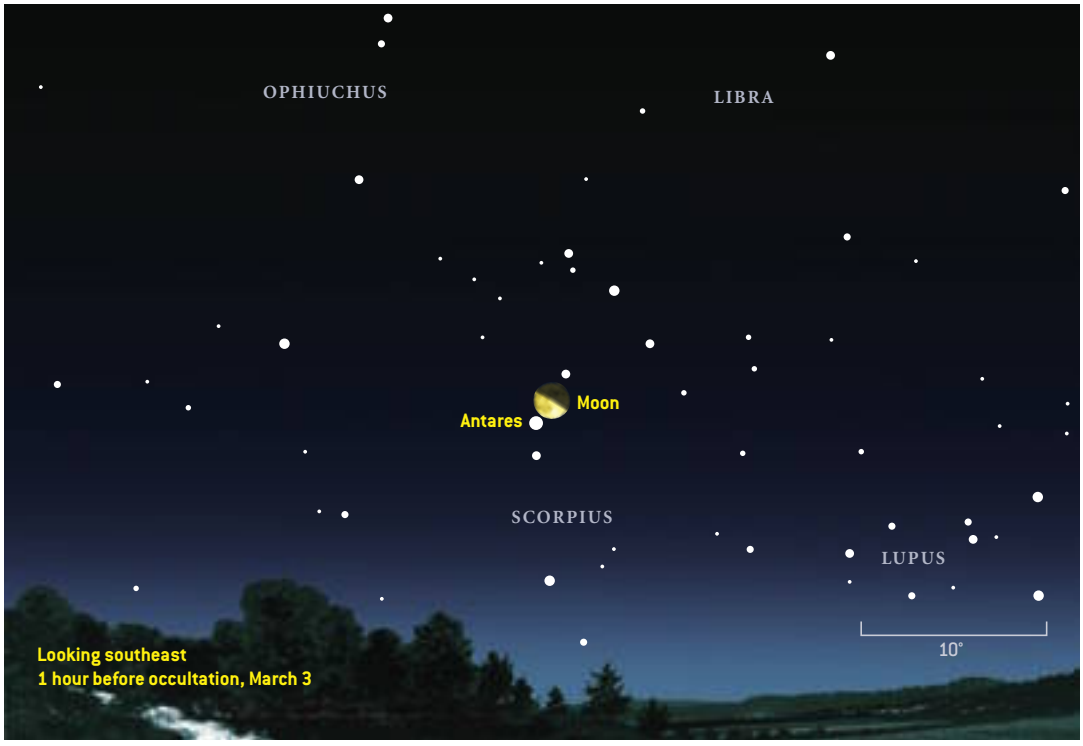
Watching the Moon pass in front of a bright star ranks among the more dynamic events visible to backyard observers. But seeing the Moon occult a 1st-magnitude star is even better. This year features several occultations of two of these luminaries: Antares in Scorpius the Scorpion and Spica in Virgo the Maiden. So pull up a scope and get ready for some action.

ONLY FOUR 1st-MAGNITUDE STARS CAN ever be occulted by the Moon. They are Aldebaran in Taurus, Regulus in Leo, Spica in Virgo, and Antares in Scorpius. A series of occultations of both Antares and Spica begins in 2005, and many of these events can be seen from North America.

Times of occultations vary across the continent because the Moon appears in slightly different positions depending on your location. Approximate times for the best North American events are given below. To view an occultation, set up your equipment at least 30 minutes prior to the listed time. You should begin observing carefully at least 5 minutes before the start. Visit the web site of the International Occultation Timing Association at *www.lunar-occultations.com* for further details on each event.

THE MOON OCCULTS many stars in 2005. Several of these occultations involve Antares, seen here in a near-miss from 1986. LARRY LANDOLFI

In the following list, D = disappearance, R = reappearance, and T indicates an event during twilight. A grazing occultation happens when the Moon's jagged edge skims in front of the star, periodically hiding and revealing the star.



EDT:

7 Mercury passes 1.6° south of Venus, 4 A.M.

8 The Moon passes 5° north of Mercury, 2 P.M.

8 The Moon passes 3° north of Venus, 3 P.M.

Mercury is at greatest eastern elongation (26°), 11 P.M.

13 The Moon passes 0.8° south of Jupiter, 2 P.M.

17 The Moon passes 0.6° north of Antares, midnight

22 The Moon passes 4° south of Neptune, 9 A.M.

Venus passes 1.2° north of Regulus, 11 A.M.

On the morning of March 3, the leading edge of the Last Quarter Moon (its bright limb) occults Antares for observers across the mainland United States. Daylight or bright twilight interferes with the event on the East Coast.

Boston — 6:16 A.M. D, T; 7:32 A.M. R
Chicago — 4:43 A.M. D; 6:02 A.M. R, T
Miami — 6:03 A.M. D, T
New Orleans — 4:40 A.M. D; 6:02 A.M. R
San Diego — 2:21 A.M. D; 2:56 A.M. R
Vancouver — 3:12 A.M. R

The Moon occults Antares again on July 17, although this time the Moon has a waxing gibbous phase and the dark limb first covers the star. This event can be seen only from the southern and western states. The grazing occultation path runs across the middle of the country.

Miami — 11:45 P.M. D; 12:41 A.M. R
New Orleans — 10:34 P.M. D; 11:04 P.M. R (Graze track less than 100 miles to the north)
San Diego — 7:13 P.M. D, T; 8:11 P.M. R, T

A waning crescent Moon occults Spica on December 25 for observers in the northwestern United States. The graze track runs from between Vancouver, British Columbia, and Portland, Oregon, through Utah south of Salt Lake City, and through a point just south of Albuquerque.

Salt Lake City — 6:35 A.M. D; 7:08 A.M. R, T
Vancouver — 5:16 A.M. D; 5:47 A.M. R

Explore the summer sky

The richness of the summer sky is exemplified by the Milky Way. Stretching from the northern horizon in Perseus, through cross-shaped Cygnus overhead, and down to Sagittarius in the south, the Milky Way is packed with star clusters, nebulae, double stars, and variable stars.

Let's start with the Big Dipper, our perennial signpost, which lies in the northwest. Overhead is Vega in Lyra the Harp. It forms one corner of the Summer Triangle, a conspicuous asterism of three stars. Near Vega lies the famous double-double Epsilon (ε) Lyrae. Two 5th-magnitude stars lie 3' apart and can be split using binoculars. And each of these stars is a telescopic double.

To the east of Vega lies the Triangle's second star: Deneb in Cygnus the Swan. Deneb marks the tail of this graceful bird and Albireo, the incomparable double star, its head. Altair, the brightest star in Aquila the Eagle, is the Triangle's third vertex.

Frequently overlooked, Cepheus the King lies to the north of Deneb. The southern corner of Cepheus contains a compact triangle of stars that includes Delta (δ) Cephei. This famous variable star varies regularly from magnitude 3.6 to 4.3 and back again with a 5.37-day period.

Hugging the southern horizon, the constellations Sagittarius the Archer and Scorpius the Scorpion lie in the thickest part of the Milky Way. Scorpius's brightest star, Antares, is a red supergiant with a color similar to the planet Mars.

23 Saturn is in conjunction with the Sun, 1 P.M.

The Moon passes 2° south of Uranus, 11 P.M.

27 The Moon passes 4° north of Mars, 4 P.M.

S	M	T	W	T	F	S
					1	2
3	4	5	○	7	8	9
10	11	12	13	◑	15	16
17	18	19	20	●	22	23
24	25	26	◐	28	29	30
31						

2005 aug

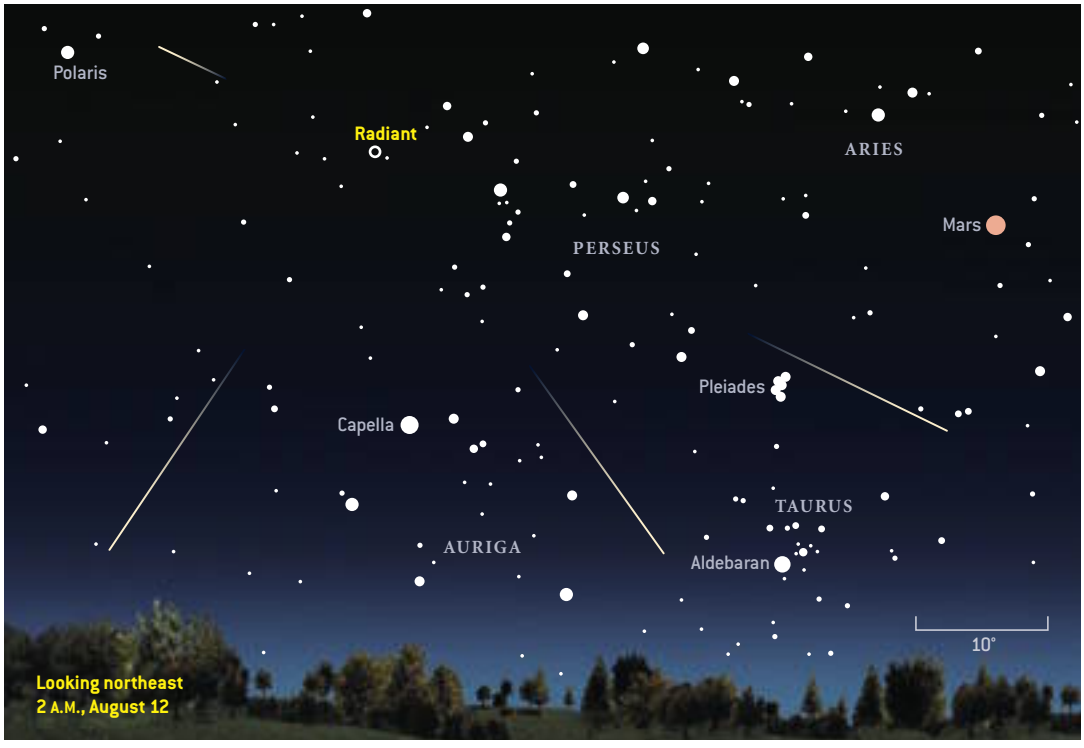
A grand year FOR PERSEIDS

For meteor observers, 2005 ranks as a down year. Only two showers promise good displays: the Eta Aquarids of early May and the Perseids of mid-August. Fortunately, the Perseids rank among the most prolific of all showers, offering rates up to 60 meteors per hour. Combine that with late-summer temperatures, and meteor watchers have a major event to anticipate.

THE MOON SETS EARLY ENOUGH FOR DARK skies to reign at the peak of this year's Perseid meteor shower. The venerable shower's long period of activity, from around July 23 to August 22, provides ample opportunity for everyone to see lots of meteors. While popular culture expects you to make a wish with each passing speck of bright, burning dust, the night of peak activity provides enough meteors for even the most creative wish-maker to run out of ideas.

The peak of the 2005 shower occurs on the morning of August 12. The nearly First Quarter Moon sets around 11:30 P.M. local daylight time, just as the radiant rises in the northeastern sky. The radiant — the point from which the meteors appear to come — lies in Perseus and climbs higher after midnight. Best viewing comes in the predawn hours, when Earth runs into the meteor stream head-on. You can expect to see roughly one meteor per minute then under a dark sky. Earlier in the night, the radiant appears lower in the sky, and fainter meteors don't show up as well. Experienced

A PERSEID METEOR FLARES into brilliance on a balmy August night. Conditions for this year's shower should be near perfect. BARRY E. LEVIN



EDT:

5 Mercury is in inferior conjunction, 8 P.M.

7 The Moon passes 1.2° north of Venus, midnight

8 Neptune is at opposition, noon

10 The Moon passes 1.3° south of Jupiter, 4 A.M.

12 Perseid meteor shower peaks

14 The Moon passes 0.4° north of Antares, 9 A.M.

18 The Moon passes 5° south of Neptune, 7 P.M.

20 The Moon passes 2° south of Uranus, 8 A.M.

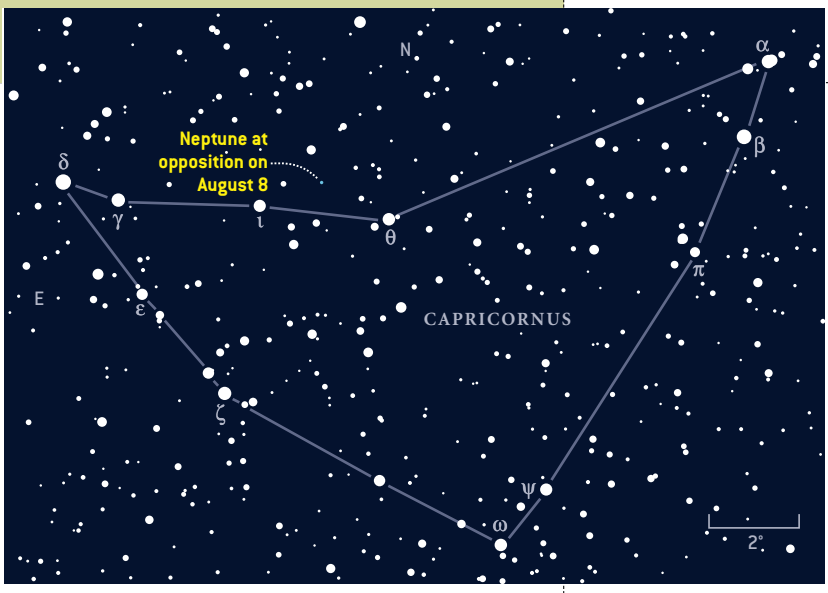
observers consider a meteor every 2 or 3 minutes a fairly active night.

Perseid meteors strike Earth's atmosphere at 37 miles per second, fast enough that even tiny particles briefly ionize a narrow trail, which we see from the ground as a meteor. The rare, larger particles produce the occasional brilliant fireballs among the more typical 2nd- and 3rd-magnitude meteors. The Perseid stream results from debris left behind by Comet Swift-Tuttle on its frequent trips around the Sun.

Neptune at opposition

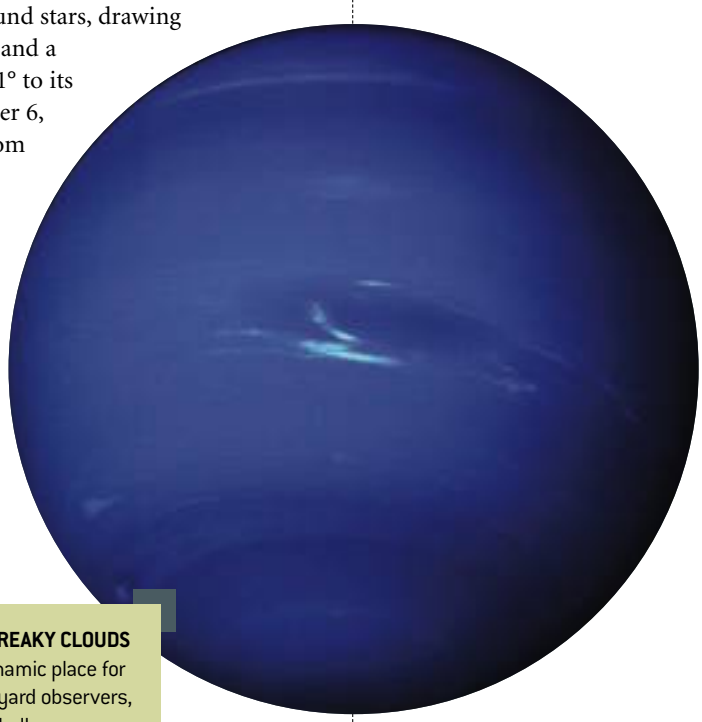
Neptune, the fourth-largest planet in the solar system and eighth in distance from the Sun, reaches opposition on August 8. Neptune lies so far from Earth — some 2.7 billion miles — that sunlight reflected off its atmosphere takes 4 hours to reach us. We see a feeble glow, which peaks during August at only magnitude 7.8. Simply seeing the planet's tiny disk through a telescope is an accomplishment.

You can find Neptune in Capricornus the Sea Goat. By 10 P.M. local daylight time in August, this inconspicuous constellation lies well above the southeastern horizon. The westernmost pair of stars in the group, Alpha (α) and Beta (β) Capricorni, usually stand out because they shine at 3rd magnitude and lie just 2° apart. Halfway across the constellation toward the east lies Theta (θ) Capricorni, a 4th-magnitude star not as easy to see from urban and suburban locations.



Neptune lies about halfway between Theta and Iota (ι) Capricorni, a similarly bright star located 4° to Theta's east. Binoculars show this stellar pair easily. At opposition in August, Neptune forms a flat triangle with these two stars, lying just above a line joining them. You'll also find a 5.3-magnitude star about 1° north of Neptune. During August and September, Neptune tracks slowly westward against the background stars, drawing closer to Theta Cap and a 6.9-magnitude star 1° to its northeast. By October 6, Neptune lies 0.1° from this fainter star.

So try to spy Neptune this summer. If this is your first time looking for the planet, it provides a fun challenge on a warm night. Once you've found it, tracking it the rest of the summer should be a breeze.



DARK SPOTS AND STREAKY CLOUDS make Neptune a dynamic place for spacecraft. For backyard observers, seeing its disk is a challenge. NASA/JPL

/// METEOR SHOWERS IN 2005

NAME	PEAK DATE	MOON'S PHASE	PROSPECTS
Quadrantids	January 3	Last Quarter	Fair
Lyrids	April 22	Waxing gibbous	Poor
Eta Aquarids	May 5	Waning crescent	Good
Perseids	August 12	Waxing crescent	Excellent
Orionids	October 21	Waning gibbous	Poor
Leonids	November 17	Full Moon	Poor
Geminids	December 13	Waxing gibbous	Poor

23 Mercury is at greatest western elongation (18°), 7 P.M.

25 The Moon passes 6° north of Mars, 3 A.M.

31 The Moon passes 5° north of Saturn, 1 P.M.

Uranus is at opposition, 11 P.M.

S	M	T	W	T	F	S
	1	2	3	○	5	6
7	8	9	10	11	◑	13
14	15	16	17	18	●	20
21	22	23	24	25	◐	27
28	29	30	31			

2005 sept

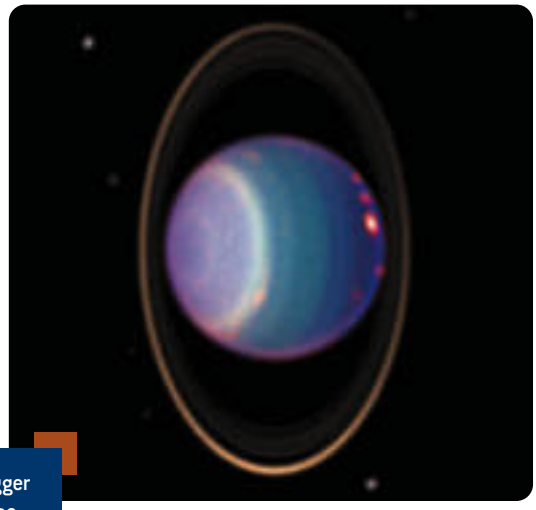
URANUS
at its best

Two distant gas-giant planets, Uranus and Neptune, reach opposition about three weeks apart. Neptune arrives at this advantageous position — when a planet appears brightest and largest — in the first half of August. Uranus follows suit as the calendar changes to September. So grab your binoculars and have a look at these distant solar system citizens.

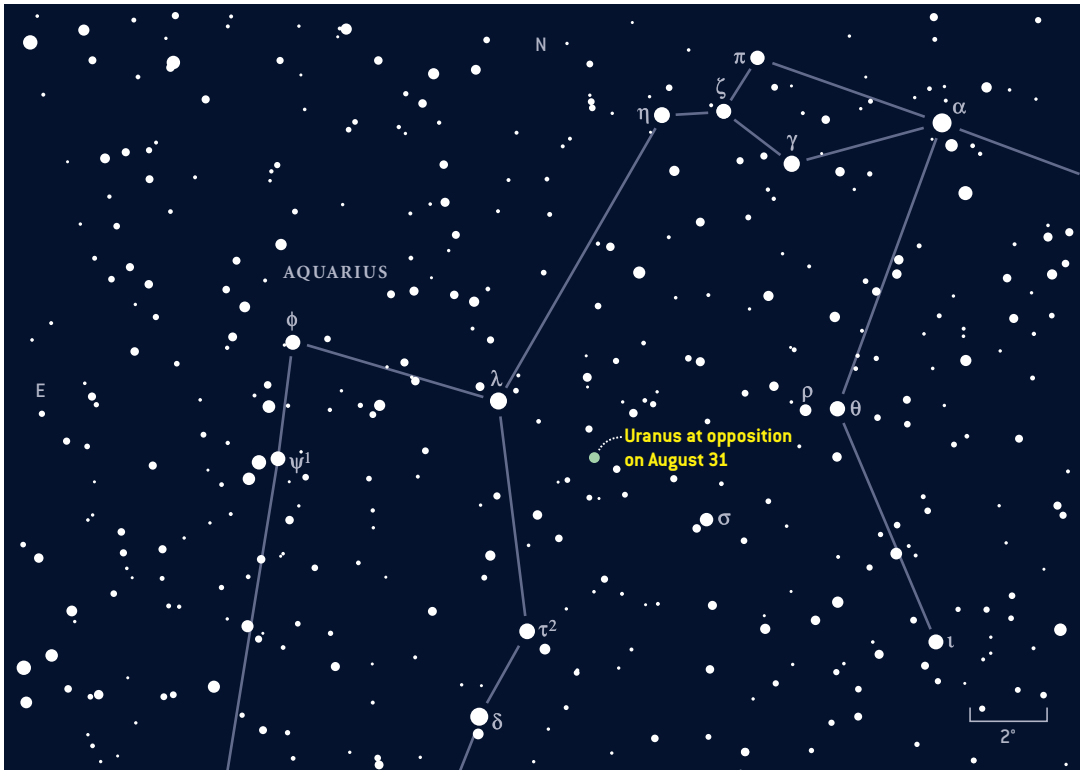
URANUS REACHES OPPOSITION ON THE final night of August, then moves into the evening sky for September. It lies nearly a billion miles closer to us than Neptune, and because the two have roughly the same physical size, Uranus appears larger in a telescope. Uranus also glows brighter than Neptune, peaking at magnitude 5.7.

Uranus begins its retrograde path, tracking westward against the background stars, in mid-June. It will lie 1° southwest of Lambda (λ) Aquarii then, a 3.7-magnitude star on the eastern side of Aquarius the Water-bearer. The retrograde path continues through mid-November as Uranus traverses a sparse region of sky.

Lambda remains the only moderately bright star to guide you in locating the planet this summer.



BLUE-GREEN URANUS looks bigger and glows brighter than Neptune, but Uranus's clouds and rings lie well beyond the range of backyard telescopes. K. SEIDELMANN (USNO) AND NASA



EDT:

2 Venus passes 1.4° south of Jupiter, 8 A.M.

4 Mercury passes 1.1° north of Regulus, 7 A.M.

5 Venus passes 1.8° north of Spica, 5 P.M.

6 The Moon passes 1.8° south of Jupiter, 8 P.M.

7 The Moon passes 1.3° north of Spica, 2 A.M.

The Moon passes 0.6° south of Venus, 5 A.M.

10 The Moon passes 0.2° north of Antares, 4 P.M.

15 The Moon passes 5° south of Neptune, 4 A.M.

During the first two weeks of September, Uranus lies practically midway between Lambda and Sigma (σ) Aquarii, a 4.8-magnitude star 6° southwest of Lambda. The planet should be easy to pick up in binoculars because few stars of similar brightness lie in the area.

Once you find Uranus, swing your telescope to it. The disk measures 3.7" across at maximum and sports a pale blue-green hue. Experienced digital imagers might be able to pull out clear images of the disk, but it's a challenge given the vagaries of Earth's atmospheric turbulence.

Three weeks after opposition, on September 18, Uranus appears to acquire an abnormally bright moon. On this night, the planet lies only 0.05° north of a nondescript, 6.7-magnitude star. Unfortunately, the nearly Full Moon stands 30° east of the planet that night, making observations more difficult.

Explore the autumn sky

The cool nights of autumn are here to remind us that winter's chill is not far off. As the brilliant stars of the Summer Triangle descend in the west, a rather bland-looking region replaces them. But don't let initial appearances deceive you. Hidden in the fall sky are gems equal to summertime's.

The Big Dipper swings low this season, and for parts of the southern United States, it actually sets. Cassiopeia the Queen, a group of five bright stars in the shape of a W or M, rides overhead, the same spot the Big Dipper reached six months ago. To the east of Cassiopeia, Perseus the Hero rises high. Nestled between these two groups is the Double Cluster — NGCs 869 and 884 — a wondrous sight through binoculars or a low-power telescope.

Our view to the south of the Milky Way is in the opposite direction of what was visible in spring. This allows us to look at the Local Group of galaxies. Due south of Cassiopeia is the Andromeda Galaxy (M31), a 4th-magnitude smudge of light that passes overhead around 9 P.M. in mid-November. Farther south, between Andromeda and Triangulum, lies M33, a sprawling face-on spiral galaxy that's best seen with binoculars or a rich-field telescope.

The Great Square of Pegasus passes just south of the zenith. Four 2nd- and 3rd-magnitude stars form the Square, but few stars can be seen inside it. If you draw a line between the two stars on the right side of the Square and extend it southward, you'll find 1st-magnitude Fomalhaut in Piscis Austrinus the Southern Fish. Fomalhaut is the solitary bright star low in the south.

To the east of the Square lies the Pleiades star cluster (M45) in Taurus, which reminds us of the forthcoming winter. By late evening in October and early evening in December, both Taurus and Orion have cleared the horizon. In concert with the reappearance of these winter constellations, the view to the northwest finds summertime's Cygnus and Lyra about to set.

16 The Moon passes 2° south of Uranus, 5 P.M.

17 Mercury is in superior conjunction, 11 P.M.

21 Jupiter passes 3° north of Spica, 6 P.M.

22 The Moon passes 6° north of Mars, 3 A.M.

22 Equinox (northern autumn/southern spring begins), 6 P.M.

28 The Moon passes 5° north of Saturn, 1 A.M.

S	M	T	W	T	F	S
				1	2	○
4	5	6	7	8	9	10
◑	12	13	14	15	16	●
18	19	20	21	22	23	24
◐	26	27	28	29	30	

2005

oct

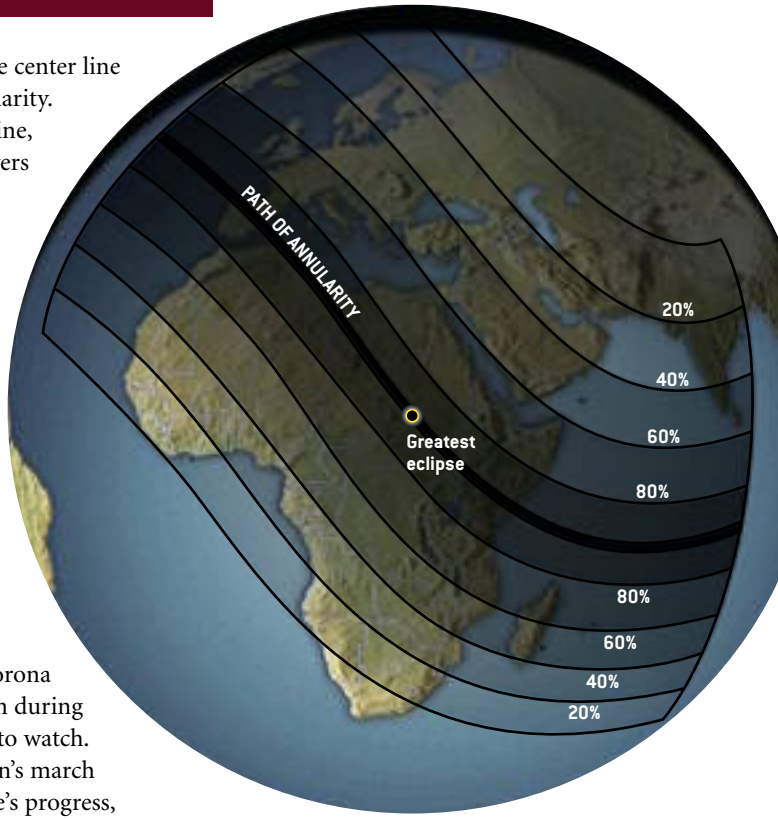
A ring of SUNLIGHT

Two solar eclipses vie for attention in 2005. On April 8, the Moon blocks the Sun totally from view for up to 42 seconds. The catch: You have to be in the South Pacific to see it. Then on October 3, people in parts of Europe and Africa will see a ring of sunlight for more than 4 minutes. Observers will have to wait until March 2006 for their next long view of totality.

THE IBERIAN PENINSULA WILL BE THE center of the astronomical universe this October as the Moon's shadow sweeps across the region. On October 3, the Moon will pass directly in front of the Sun. Because the Moon lies relatively far from Earth that day, it doesn't appear big enough to block the Sun totally from view. A ring of sunlight will remain at maximum eclipse. Such eclipses are called annular, from the Latin word *anulus*, meaning "ring." Ninety-six percent of the Sun will be covered during this annular eclipse, bringing a decided gloom to areas along the path.

A GOLDEN RING OF LIGHT will greet observers in northern Portugal, central Spain, and a thin strip of Africa on October 3. RON LEE

After sweeping across northern Portugal and central Spain, the path traverses the Mediterranean Sea and heads into Africa. There, it makes a beeline across the continent from northeastern Algeria to southern Somalia. Every land-based location along the center line experiences at least 4 minutes of annularity. Madrid, which lies just off the center line, gets 4 minutes and 11 seconds. Observers across most of Europe and Africa and much of southern Asia will witness a partial solar eclipse.



Even though 96 percent of the Sun is hidden from view, the remaining 4 percent can do great harm to anyone who looks directly at it without proper eye protection. Either project an image of the Sun onto a piece of white cardboard or use a high-quality solar filter that blocks almost all the Sun's visible, ultraviolet, and infrared radiation. Never look directly at the Sun without good eye protection.

Unfortunately, the Sun's glorious corona and ruddy prominences remain hidden during an annular eclipse. Still, there's plenty to watch. Although someone following the Moon's march across the Sun's face will see the eclipse's progress,

EDT:

- 3 Annular solar eclipse, 6 A.M.
- 4 Mercury passes 2° north of Spica, 4 A.M.
- 6 Mercury passes 1.5° south of Jupiter, 3 A.M.
- 7 The Moon passes 1.4° south of Venus, 2 A.M.
- 7 The Moon passes 0.2° north of Antares, 9 P.M.
- 12 The Moon passes 5° south of Neptune, 11 A.M.
- 14 The Moon passes 3° south of Uranus, 1 A.M.
- 16 Venus passes 1.6° north of Antares, 2 P.M.

to others, the signs are subtle until about half the Sun is blocked. As the source of light in the sky grows smaller, you'll start to notice that shadows appear sharper. Once the Moon covers about 80 percent of the Sun, shift your attention from the sky to the ground. Look closely at sunlight filtering through the leaves of nearby trees and bushes, and you'll see hundreds or thousands of tiny images of the crescent Sun. The openings between the leaves serve as pinholes that project images of the eclipsed Sun.

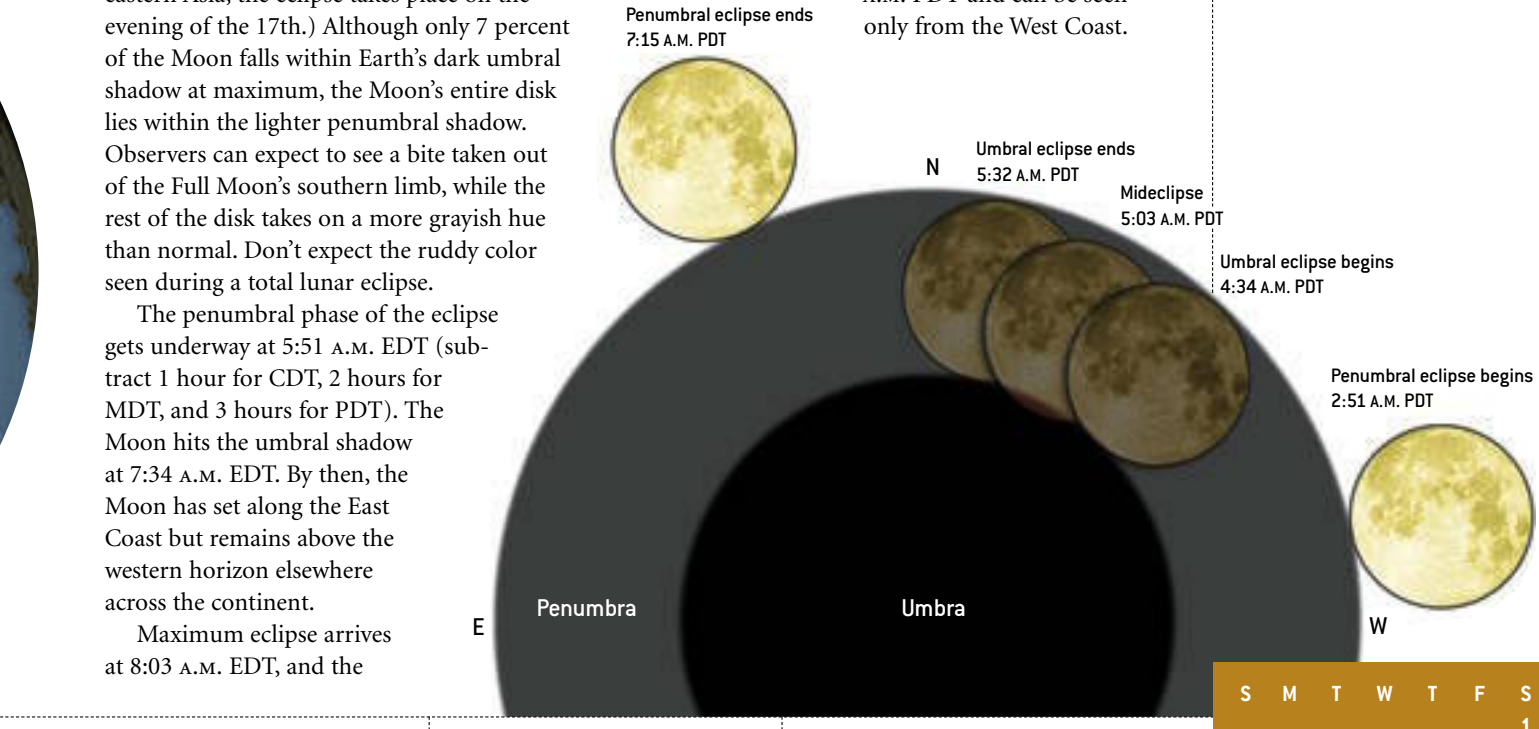
Into a partial shadow

Two weeks after the Moon blocks the Sun from view, Earth returns the favor. On the morning of October 17, people in most of North America have the chance to see the Moon pass into Earth's shadow. (For those in Australia, New Zealand, and eastern Asia, the eclipse takes place on the evening of the 17th.) Although only 7 percent of the Moon falls within Earth's dark umbral shadow at maximum, the Moon's entire disk lies within the lighter penumbral shadow. Observers can expect to see a bite taken out of the Full Moon's southern limb, while the rest of the disk takes on a more grayish hue than normal. Don't expect the ruddy color seen during a total lunar eclipse.

The penumbral phase of the eclipse gets underway at 5:51 A.M. EDT (subtract 1 hour for CDT, 2 hours for MDT, and 3 hours for PDT). The Moon hits the umbral shadow at 7:34 A.M. EDT. By then, the Moon has set along the East Coast but remains above the western horizon elsewhere across the continent.

Maximum eclipse arrives at 8:03 A.M. EDT, and the umbral phase concludes at 8:32 A.M. EDT. By that time, the Moon has set everywhere east of a line that runs from eastern Texas north to the arrowhead of Minnesota. The penumbral phase ends at 7:15 A.M. PDT and can be seen only from the West Coast.

THE MOON'S SOUTHERN LIMB will darken during a partial lunar eclipse on October 17, mimicking this view from the October 1987 penumbral eclipse. SHERRI MARTIN



17 Partial lunar eclipse, 8 A.M.

19 The Moon passes 5° north of Mars, 9 A.M.

21 Orionid meteor shower peaks

22 Jupiter is in conjunction with the Sun, 9 A.M.

25 The Moon passes 4° north of Saturn, 1 P.M.

31 The Moon passes 1.2° north of Spica, 2 P.M. EST

S	M	T	W	T	F	S
						1
2	○	4	5	6	7	8
9	◑	11	12	13	14	15
16	●	18	19	20	21	22
23	◐	25	26	27	28	29
30	31					

MARS returns to glory

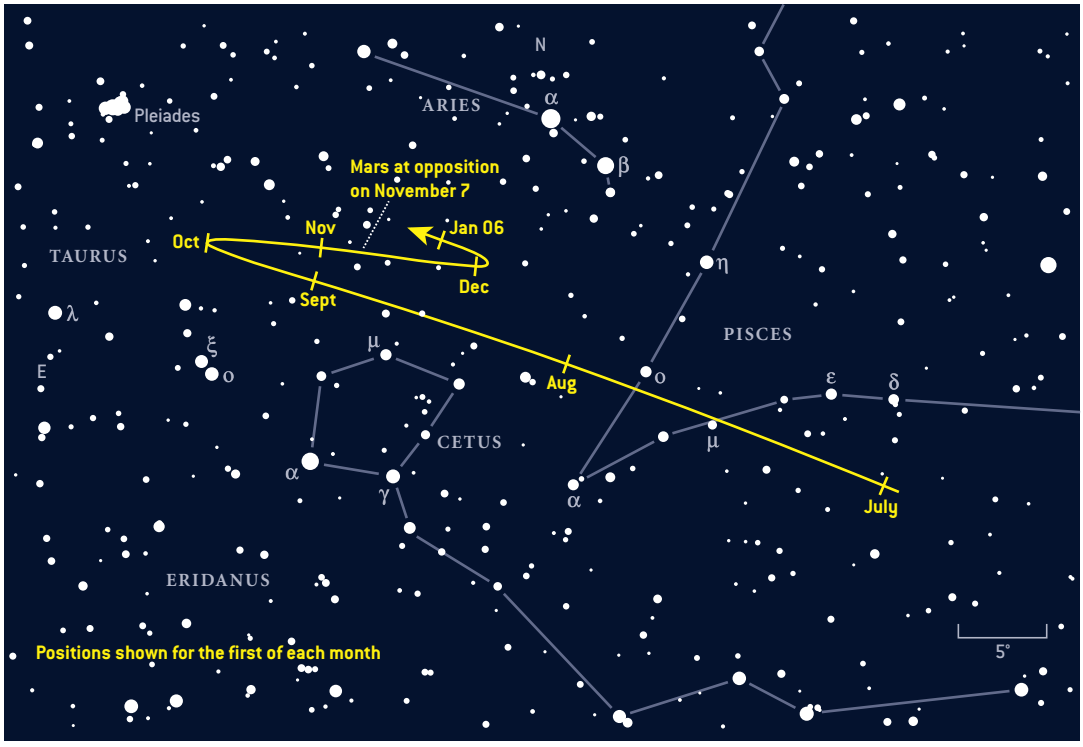
2005 nov

Memories remain fresh of the appearance of Mars during the summer of 2003. The Red Planet came closer to Earth than at any time in 60,000 years, and it won't be as close again for more than 20,000 years. But Mars viewers shouldn't toss their scopes yet — autumn 2005 brings Mars close again, and it will offer great views to anyone who makes the effort.

MARS FOLLOWS ITS RECORD-BREAKING 2003 opposition with an excellent return this autumn. Mars will reach a maximum apparent size of 20.2", 5" smaller than in 2003 but significantly bigger than it is at a typical opposition. Although Mars won't be as close as it was two years ago, it will be at a much higher elevation — 30° higher for Northern Hemisphere observers — giving long periods with potentially sharper views.

You actually can see Mars throughout 2005. At the start of the year, it appears in the predawn sky among the stars of Scorpius. Then, it slowly makes its way across Ophiuchus, Sagittarius, and Capricornus, where it passes 1.2° south of Neptune on April 12/13. A month later, on May 14, Mars stands the same distance south of Uranus. The two planets lie in the eastern section of

MARS MANIA will sweep the globe again in late 2005, as the Red Planet puts on a show just slightly less grand than it did in 2003.
NASA, J. BELL (CORNELL UNIVERSITY), AND M. WOLFF (SSI)



EST:

3 Mercury is at greatest eastern elongation (24°), 11 A.M.

3 Venus is at greatest eastern elongation (47°), 2 P.M.

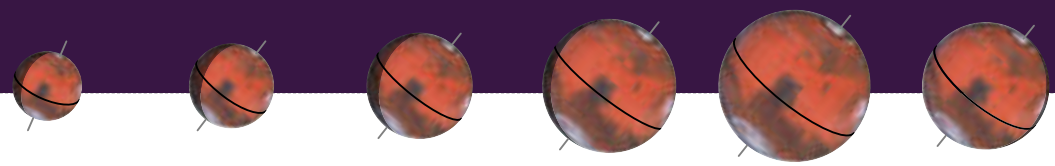
4 The Moon passes 0.2° north of Antares, 2 A.M.

5 The Moon passes 1.4° south of Venus, 2 P.M.

7 Mars is at opposition, 3 A.M.

8 The Moon passes 5° south of Neptune, 3 P.M.

10 The Moon passes 3° south of Uranus, 5 A.M.



July 1, 2005
Disk size = 9.3"
Magnitude = –0.1

August 1, 2005
Disk size = 11.3"
Magnitude = –0.5

September 1, 2005
Disk size = 14.1"
Magnitude = –1.0

October 1, 2005
Disk size = 17.8"
Magnitude = –1.7

November 1, 2005
Disk size = 20.2"
Magnitude = –2.3

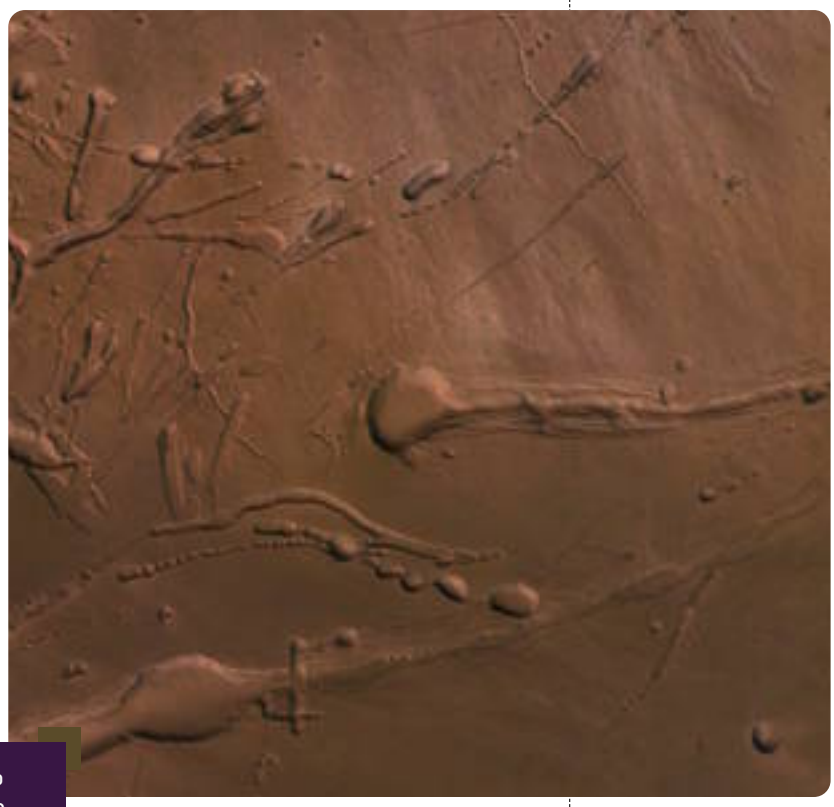
December 1, 2005
Disk size = 16.9"
Magnitude = –1.6

Aquarius. Mars appears bright, shining at magnitude 0.5, but with a diameter of just 7", it won't show much detail through a telescope.

Attention will grow when Mars crosses the 10"-diameter threshold on July 13. From then through the end of the year, Mars presents a fine telescopic target. July finds Mars rising around midnight and standing 45° above the southeastern horizon as twilight starts to paint the sky. This altitude already beats the best of the 2003 apparition by 10°. By the end of July, Mars has brightened a whole magnitude and dominates the morning sky, gleaming at magnitude –0.5.

Don't miss these early opportunities for viewing Mars. By the time opposition rolls around on November 7, the best viewing period already will be half over. Although there were no global dust storms in 2003, there's no guarantee we'll be so lucky this time. The Red Planet reaches perihelion, its closest approach to the Sun, in mid-July, and dust storms frequently appear around this time.

Mars begins its retrograde (westward) motion in early October, when it lies on the border between Taurus and Aries. After spending two weeks in Taurus, the planet's path carries it back into Aries. Mars remains among the stars of the Ram for the rest of the year.



MARS EXPRESS will continue to send back images, like this one of Ascraeus Mons, through 2005. This year also sees NASA launch its Mars Reconnaissance Orbiter. ESA

The Red Planet appears at its finest in late October and early November. For a period of two weeks, from October 23 to November 6, the planet spans at least 20.0". Mars actually comes closest to Earth — and thus appears its largest — a week before its November 7 opposition. On October 30, it lies 43.1 million miles away and has a diameter of 20.2". Mars shines brightest at opposition, however, reaching magnitude –2.3. It then rises at sunset and appears highest in the south around midnight. Mars lies 65° high as seen from a latitude of 40° north and completely dominates the southern sky.

The most famous feature on the Red Planet is Syrtis Major. Its distinctive dark, triangular shape will be well-placed for observation during the peak viewing period. On October 24, it lies on the central meridian of Mars at 9 P.M. EST. One week later, Syrtis Major reaches the disk's center at about 1 A.M. EST. By November 7, the feature returns to view in the early morning hours.

After opposition, Mars fades quickly, dimming to magnitude –1.0 by December 19. By the second half of December, Mars resumes its easterly trek relative to the stars. Next February, the planet will pass 2° south of the Pleiades star cluster, providing a wonderful contrast between its ruddy hue and the cluster of blue-white stars.

15 The Moon passes 3° north of Mars, 1 A.M.

17 Leonid meteor shower peaks

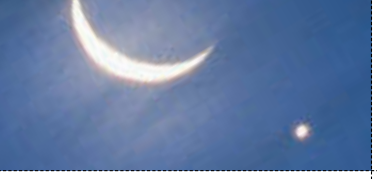
21 The Moon passes 4° north of Saturn, 10 P.M.

24 Mercury is in inferior conjunction, 11 A.M.

27 The Moon passes 1.1° north of Spica, 11 P.M.

29 The Moon passes 3° south of Jupiter, 3 A.M.

S	M	T	W	T	F	S
		○	2	3	4	5
6	7	◑	9	10	11	12
13	14	●	16	17	18	19
20	21	22	◐	24	25	26
27	28	29	30			



The brilliant EVENING STAR

2005 dec

Few sights impress casual stargazers more than seeing the brilliant planet Venus gleaming in a twilit sky. This year provides several opportunities to Venus-gaze. The planet takes on the role of "morning star" in the first weeks of 2005, then it returns as the "evening star" during the second half of the year. Venus appears most prominent in November and December.

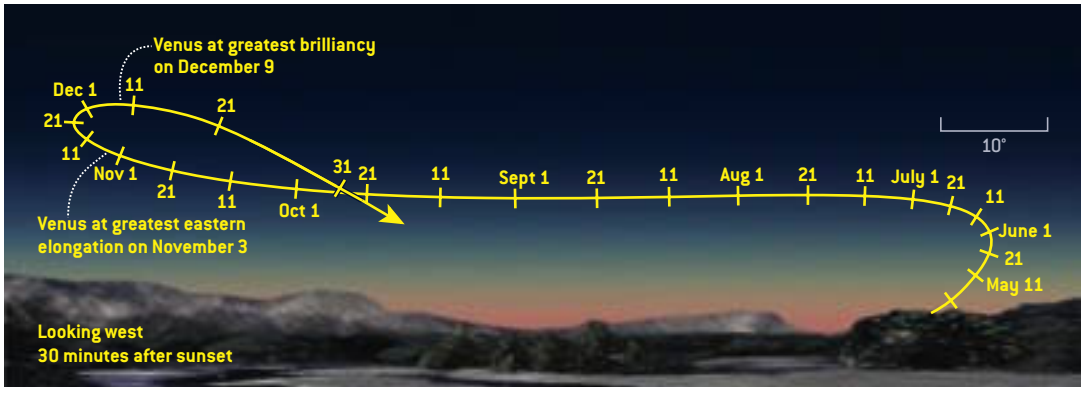
VENUS APPEARS LOW IN THE SOUTHEAST before dawn for the first few weeks of January, passing just 1.2° below Mercury on New Year's morning. Venus becomes lost in the solar glare by the end of the month and does not return to view until May, when it lies in the evening sky. On May 20, it sets one hour after the Sun and appears among the background stars of Taurus the Bull. At the same time, Saturn lies about 35° above the western horizon. Over the next several weeks, Venus plays catch-up with Saturn. A dramatic conjunction between these two and Mercury occurs in late June.

During June, Venus races across the constellation Gemini the Twins. A slender crescent Moon passes 6° above Venus on the 8th. One evening later, the Moon lies 5° north of Saturn. By the middle of the month, Mercury comes into view below Venus and Saturn and each day climbs closer to the planet duo. The three planets appear closest together on June 25, when they lie within 1.5° of one another. Watch each evening leading up to and following this date as the planets change relative positions in a wonderful celestial dance.

VENUS GLEAMS BRILLIANTLY in the evening sky at the end of 2005, but it appears truly striking when paired with the Moon, as it will be on December 4. JOHN McNEAL

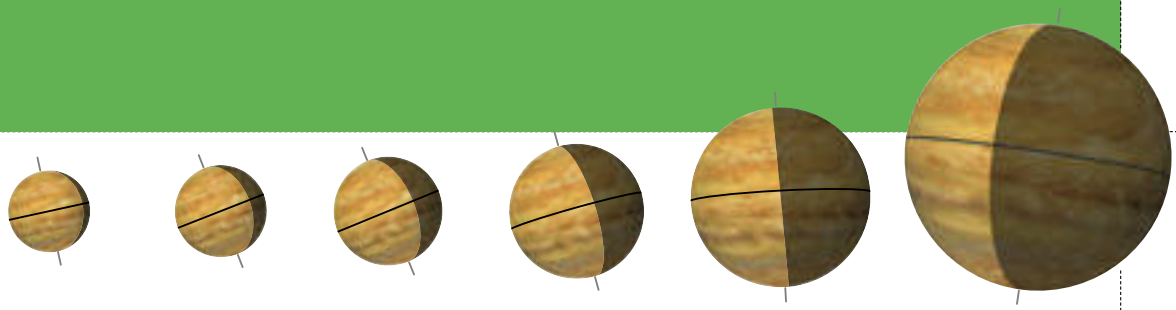
On June 25, Venus and Mercury lie 0.5° apart, with Saturn 1.3° south of Venus. Venus appears far brighter than the other two, and Mercury is a shade brighter than Saturn. The next night, Venus stands 1.7° above Saturn. Venus and Mercury lie 0.2° apart and can be seen in the same telescopic field of view. Mercury shows a slightly more than half-illuminated disk, while Venus appears 92-percent lit. By June 27, Mercury has moved from west of Venus to southeast but still lies within 0.2°. Both Venus and Mercury have started to pull away from Saturn, which now lies 2.5° below Venus.

While Saturn quickly falls into the evening twilight, Mercury and Venus remain visible each



EST:

- 4 The Moon passes 2° south of Venus, 1 P.M.
- 5 The Moon passes 4° south of Neptune, 10 P.M.
- 7 The Moon passes 2° south of Uranus, 11 A.M.
- 9 Asteroid Juno is at opposition, 3 A.M.
- 9 Venus is at greatest brilliancy (magnitude −4.7), 8 A.M.
- 11 The Moon passes 1.3° north of Mars, midnight
- 12 Mercury is at greatest western elongation (21°), 8 A.M.
- 13 Geminid meteor shower peaks



July 1, 2005
Disk size = 11.0"
Magnitude = –3.9

August 1, 2005
Disk size = 12.4"
Magnitude = –3.9

September 1, 2005
Disk size = 14.6"
Magnitude = –4.0

October 1, 2005
Disk size = 18.1"
Magnitude = –4.2

November 1, 2005
Disk size = 24.3"
Magnitude = –4.4

December 1, 2005
Disk size = 35.9"
Magnitude = –4.6

night as they cross into Cancer the Crab. On July 3, Mercury and Venus straddle the Beehive star cluster (M44), and 1.2° separate the planets. Mercury has started to fade, however, and it becomes more difficult to see. An hour after sunset, the pair lies 5° high in the west-northwest. If you have a clear horizon, see if you can spot the Beehive with binoculars as the planets set. The transparency of the atmosphere will play a critical role in your success.

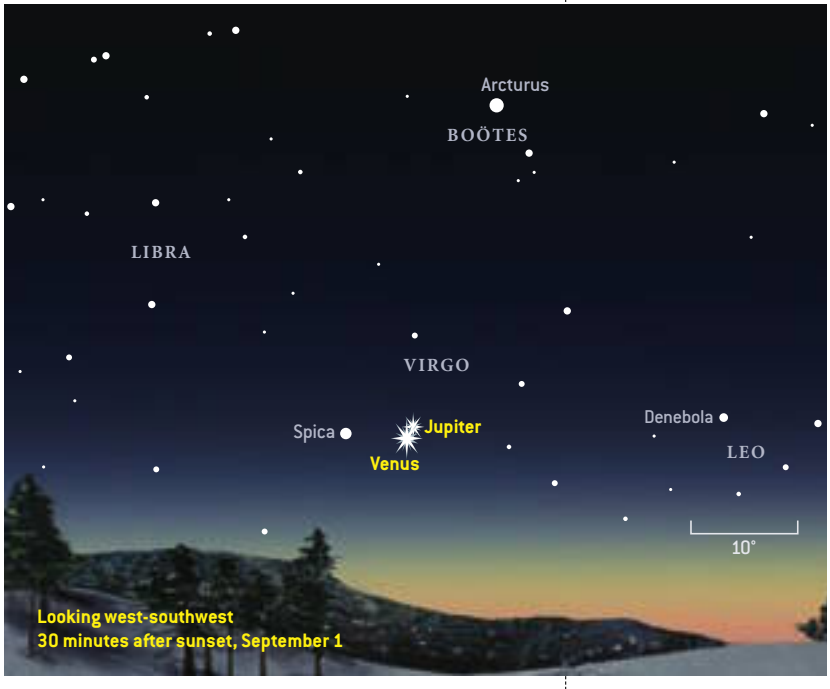
On July 8, a crescent Moon stands 3° above Venus, while less than four Moon-widths separate Venus and Mercury. Two weeks later, on the 22nd, Venus lies 1.2° north of Regulus, the brightest star in Leo the Lion. By then, Mercury has sunk back into the Sun's glow.

Throughout August, Venus closes the gap with the second brightest planet, Jupiter. On September 1, Venus appears just 1.2° below Jupiter, forming the finest planetary conjunction of the year. The bright star Spica in Virgo then lies 5° to the left of Venus. Five nights later, a waxing crescent Moon joins Venus, Jupiter, and Spica in an elegant setting in the west-southwest 30 to 60 minutes after sunset.

Venus continues to hug the horizon throughout this period because the ecliptic — the apparent path of the Sun across the sky, which the Moon and planets also follow closely — makes a shallow angle to the western horizon after sunset at this time of year. On October 16, Venus passes 1.6° north of Antares in Scorpius. On November 3, the planet reaches greatest elongation, lying 47° east of the Sun. Still, Venus lies only 12° high in the southwest an hour after sunset. Two nights later, a crescent Moon meets Venus in Sagittarius. Venus appears as a brilliant diamond then, shining at magnitude –4.4 against the glow of the Milky Way. This provides a fine opportunity for some stunning astrophotography.

This evening apparition of Venus provides an excellent opportunity to watch the size and phase of the brightest planet change. When Venus first appears in the evening sky in May and June, it shows a 10"-diameter disk that's more than 90-percent illuminated. By August 31, the phase has shrunk to three-quarters lit while the size has grown to 15". Venus appears half-lit and 25" across at greatest elongation.

The final two months of the year see Venus change at an even greater pace. Its disk more than doubles in size between early November and late December, at which time it spans 58". Meanwhile, the phase shrinks to 33-percent lit on November 30, 25-percent lit on December 10, and 20-percent lit five days later. On New Year's Eve, Venus displays a 6-percent-illuminated disk and sets nearly 2 hours after the Sun. A



15 Pluto is in conjunction with the Sun, 11 P.M.

19 The Moon passes 4° north of Saturn, 4 A.M.

21 Solstice (northern winter/southern summer begins), 2 P.M.

25 The Moon passes 0.9° north of Spica, 9 A.M.

26 The Moon passes 4° south of Jupiter, 11 P.M.

28 The Moon passes 0.2° north of Antares, 9 P.M.

S	M	T	W	T	F	S
				○	2	3
4	5	6	7	◑	9	10
11	12	13	14	●	16	17
18	19	20	21	22	◐	24
25	26	27	28	29	○	31

Learn the

Constellations can help you sort the twinkling dots scattered across the night sky. Connect the stars to see what deep-sky wonders emerge. /// BY GLENN CHAPLE

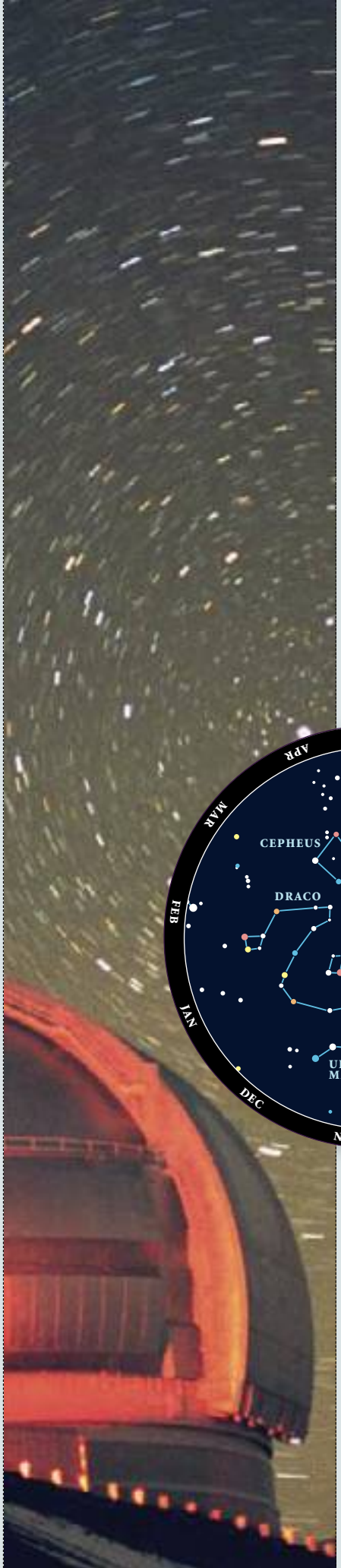
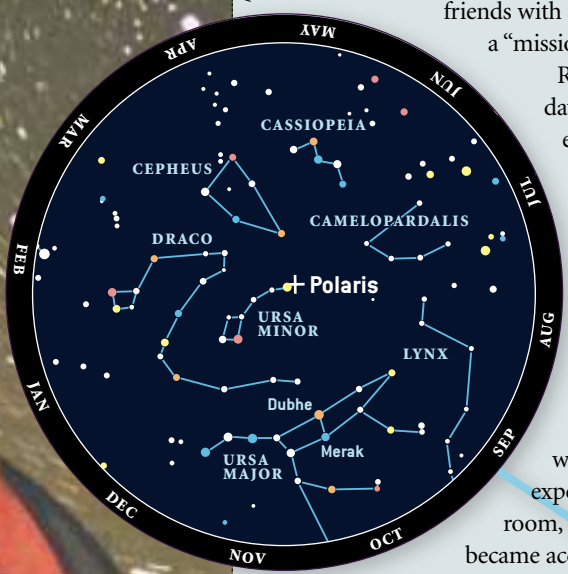


PHOTO COURTESY OF GEMINI OBSERVATORY



ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY AND JAY SMITH

IF YOU'RE A NEWCOMER TO AMATEUR astronomy, eager to begin exploring the night sky, you'll have to overcome one of astronomy's biggest hurdles — learning to identify the constellations. After all, you can't find the Andromeda Galaxy if you can't find Andromeda. Trying to make sense of those myriad stellar specks overhead might seem intimidating, but making friends with the stars needn't be a "mission impossible."

Remember your first day of school — entering that classroom and finding yourself confronted by a roomful of unfamiliar faces? Even on that first day, you probably made a few friends. Through them, and with your day-to-day exposure to the classroom, you gradually became acquainted with all of your classmates. Learning the constellations is like that. With a little help from your friends (easy-to-find guidepost constellations) and a willingness to "show up for class" on successive nights, you'll soon feel comfortable in your nighttime surroundings. So relax. It's time to go to school and meet some new friends!

North circumpolar constellations

We begin in the northern sky, realm of those always-visible star groups known as the north circumpolar constellations. The most prominent figure is the **Big Dipper** (Note: The Big Dipper is *not* a constellation). These bright stars — four forming the "bowl," three more tracing out the "handle" — create one of the most recognizable patterns in the night sky, an ideal guide for locating surrounding constellations.

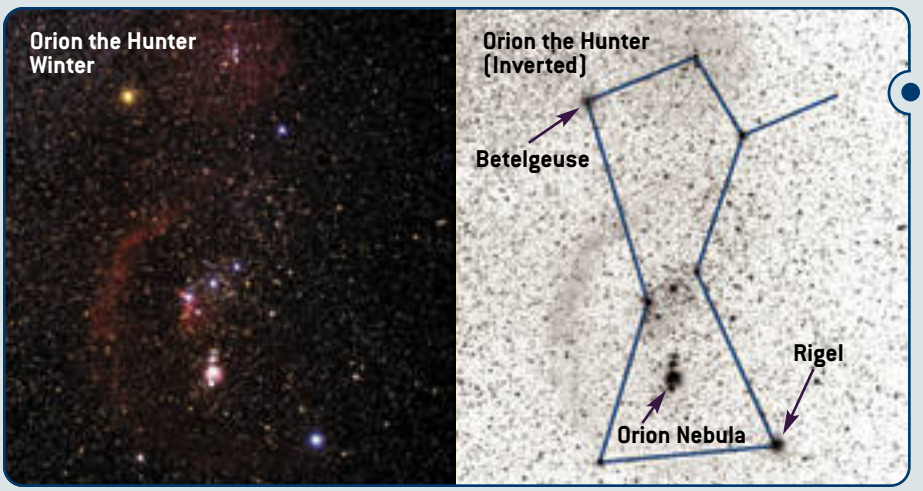
As any good Boy or Girl Scout will attest, you can find *Polaris*, the North Star, by tracing a line between the stars *Dubhe* and *Merak* at the end of the bowl of the Big Dipper and extending it about five times the distance between them. When astronomical newcomers see this celebrated star for the first time, they are astonished that it isn't much brighter than the stars in the Big Dipper. Polaris is the brightest star in **Ursa Minor the Little Bear**, which contains the Little Dipper. Like its big brother, the Little Dipper is made up of seven stars — four in the bowl, and three in the handle. Because four of its stars are dim, the Little Dipper is hard to see in light-polluted skies.

If you trace a line from the bowl of the Big Dipper past the North Star and continue it an equal distance beyond, you'll arrive at an eye-catching group of stars that form a distinct letter M or W. This is **Cassiopeia, Queen of Ethiopia**.

Winter

To see the constellations that come and go with the seasons, we need to turn our backs on the north circumpolar constellations and face south. If the winter sky seems alive with stars, it's no illusion. Besides the obvious facts that the air is clear and dry then, we're looking at a star-rich region that defines one of the spiral arms of our Milky Way Galaxy. Of the twenty-one brightest stars in the entire night sky (so-called 1st-magnitude stars), seven are in this area.

constellations



ALL CONSTELLATION IMAGES: TILL CREDNER, ALLTHESKY.COM

On a winter evening, the sky is home to what most astronomers agree is the grandest of all constellations — **Orion the Hunter**. A rectangle of bright stars, which includes, at opposite corners, 1st-magnitude *Betelgeuse* and *Rigel*, is bisected by a diagonal row of three bright stars (the "belt"). Beneath the belt hangs a row of three stars — Orion's "sword." Don't be fooled by their uninspiring naked-eye appearance; the middle star in the sword isn't a star at all. It's the Orion Nebula — one of the grandest telescopic showpieces the night sky has to offer. In binoculars, it appears as a fuzzy patch of light. When you gaze at this wondrous glowing cloud, you view creation itself, for within this luminous glow, stars are being born.

Orion is the focal point of a stunning gathering of bright stars and constellations. The belt points down and to the left to a brilliant white star: *Sirius*, the brightest star in the night sky, leader of the constellation **Canis Major the Great Dog**. Sirius always dazzles, but the star especially captivates when positioned near the horizon. During winter, atmospheric refraction causes Sirius to sparkle in a rainbow of colors — a beautiful sight through binoculars or a small telescope.

Return to Orion's belt and continue up and to the right, and you arrive at a V-shaped group of stars called the Hyades. This is the "head" of **Taurus the Bull**. The reddish-orange 1st-magnitude star at the upper-left end of the V is *Aldebaran* — the eye of the Bull. Each end of the V extends outward to a star that forms one of the Bull's horns. Continuing past the Hyades, you'll see a little cluster of stars — one of the loveliest naked-eye sights in the night sky. This is the Seven Sisters, or Pleiades. Six are visible to the unaided eye under average sky conditions; binoculars reveal the seventh star, plus dozens more.

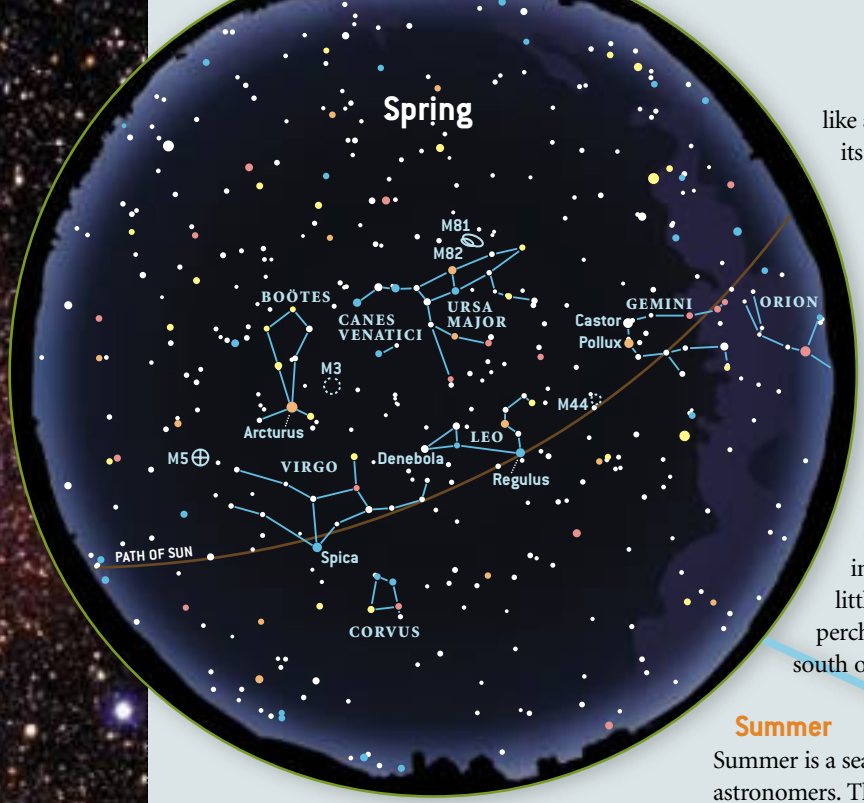
The uppermost horn of Taurus is part of a pentagon of stars that includes the bright golden-yellow star *Capella*. This pentagon is the constellation **Auriga the Charioteer**. Auriga lies above Orion and is overhead on a midwinter evening. The fact that these five stars represent a man on a chariot carrying a goat (Capella) attests to the vivid imagination of its ancient discoverers. Oh yes, that little triangle of stars beneath Capella represents the goat's three kids!

Orion's heavenly court includes **Gemini the Twins**. From Orion, extend a line upward from Rigel through Betelgeuse to this neat rectangular constellation, which contains the bright stars *Pollux* and *Castor*. In 2005, Gemini will be more aptly called the "Triplets," for Pollux and Castor will be joined by a third bright "star" — Saturn.

Midway and slightly left of a line between Sirius and the stars Pollux and Castor is the 1st-magnitude star *Procyon*. Procyon forms an equilateral triangle with Betelgeuse and Sirius. It's about all you'll see of **Canis Minor the Little Dog**.

Spring

As the days lengthen and the weather warms, Orion and his wintry retinue process slowly into the western sky. **Leo the Lion** now assumes center stage high in the south. Leo's most noticeable feature is an asterism (a grouping of stars) that reminds observers of a sickle or a backward question mark. The period on the question mark is the 1st-magnitude star *Regulus*. To the left of



like a huge kite, with Arcturus at its base.

Continuing the arc, you'll "sprint to *Spica*." This blue-white 1st-magnitude star is in **Virgo**, which is a huge, sprawling constellation.

If you look below and to the right of Spica, you'll spot a neat little group of four bright stars that resembles the outline of a sail. This is the constellation **Corvus the Crow**. I'm always impressed at how stately this little constellation looks, perched above the treetops to the south on a clear spring evening.

Summer

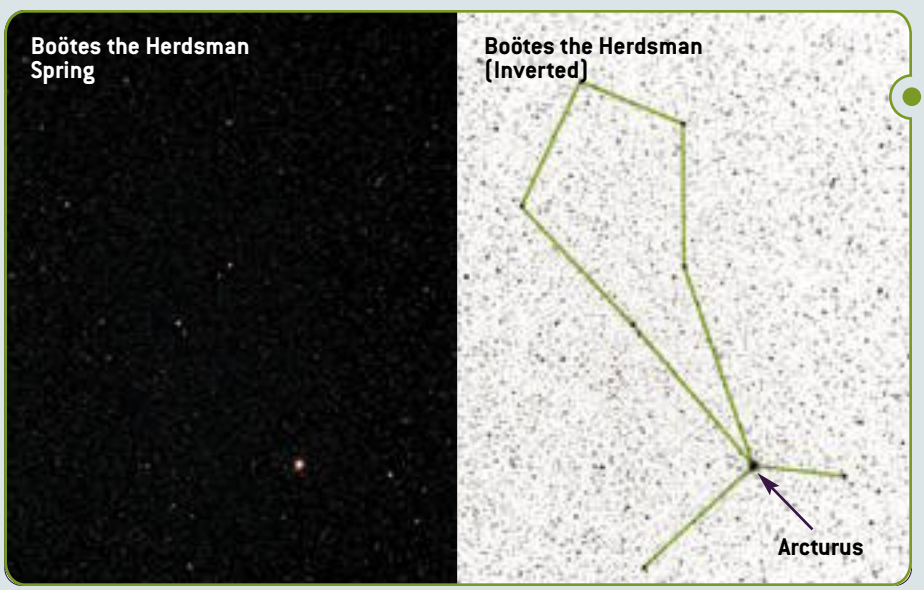
Summer is a season of mixed blessings for astronomers. The nights are warm but short and often hazy. As if that weren't bad enough, we have to contend with swarms of blood-sucking mosquitoes! Haze and insects aside, the summer sky is a veritable gallery of cosmic masterpieces. The Milky Way arches high across the sky, which is richer than its winter counterpart because we now look toward the heart of our galaxy. Dominating the evening sky are three 1st-magnitude stars forming the **Summer Triangle**. *Vega* is the brightest of the three and is located in a nifty little constellation called **Lyra the Lyre.**

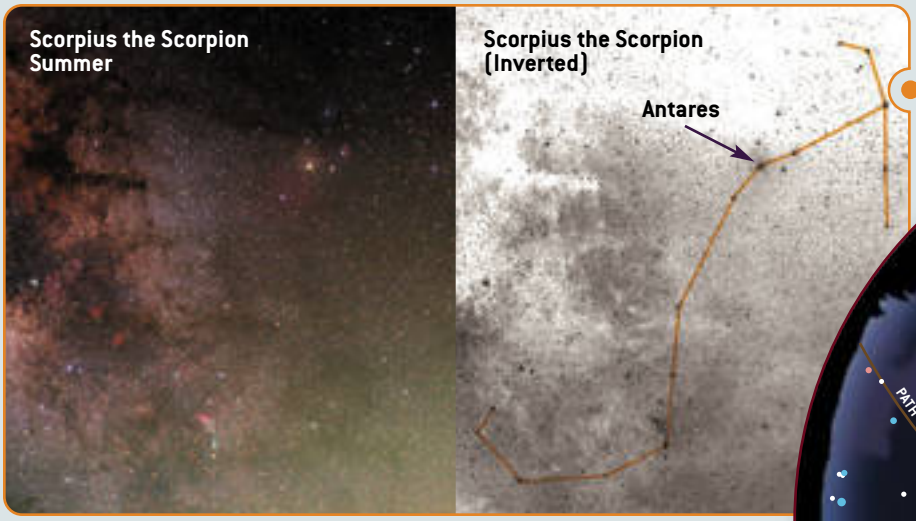
Our second Summer Triangle star, *Deneb*, is the tail of **Cygnus the Swan**. Deneb and four other bright stars of the Swan form an asterism called the Northern Cross,

the Sickle are three stars that form a right triangle. We see the Lion from the side; the Sickle outlines his head, and the triangle, his hindquarters. Viewed with a little imagination, Leo definitely sports a feline profile.

During spring, the Big Dipper appears nearly overhead from mid-northern latitudes. If you follow the handle of the Dipper away from the bowl, you'll "arc to *Arcturus*," a golden-yellow 1st-magnitude star in the constellation **Boötes the Herdsman**. The constellation itself is shaped

Glenn Chaple *is a contributing editor of* Astronomy *in his spare time and a middle school teacher in Townsend, Massachusetts.*





which is immersed in the Milky Way. Deneb is at the top of the cross, the star *Albireo* is at the base. Albireo is a double star famous for its rich colors of golden yellow and sapphire blue. The star pair can be split with binoculars, but the colors can be seen only through a telescope.

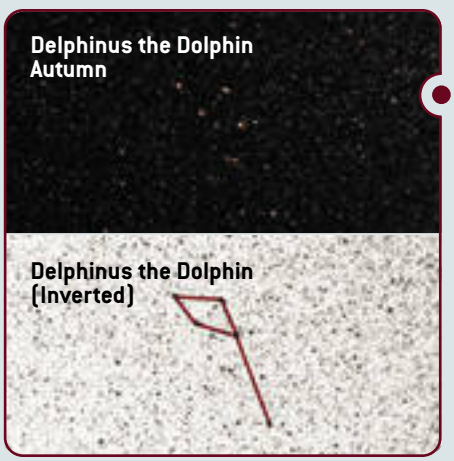
Farther south on the Milky Way is the bright star *Altair* and its parent constellation, **Aquila the Eagle**. If you follow the Milky Way from Aquila toward the southern horizon, you should find a group of stars that looks like a teapot. This asterism is part of **Sagittarius the Archer**. This constellation marks the location of our galaxy's center. The area teems with deep-sky treasures — especially bright nebulae and star clusters.

To the right of the teapot is the ruddy 1st-magnitude star *Antares*, the "heart" of **Scorpius the Scorpion**. Like the winter star Betelgeuse, Antares is a red supergiant star in the last stages of its life. A fishhook-shaped row of stars trailing down and to the left of Antares forms the Scorpion's tail and stinger, while an upright row of three stars to Antares's right marks the location of its claws.

Autumn

As the nights begin to lengthen and a chill pervades the air, the summer Milky Way exits center stage (although the Summer Triangle remains visible in the west until early winter). Following the Summer Triangle is one of the night sky's prettiest constellations — **Delphinus the Dolphin**. Four stars, arranged like a diamond, form the Dolphin's head, while a fifth creates the tail. You can imagine a dolphin leaping out of the water as you gaze at this constellation.

In its wake is a rather barren expanse of sky whose most prominent feature is the Great Square of **Pegasus the Winged Horse**. *Alpheratz* is at the top left corner of the Great Square. From here, two rows of stars branch out and up. This is the constellation **Andromeda the Princess**. And yes, it is home to the great Andromeda Galaxy. At a distance of 2.7 million light-years from Earth, it's the most remote object readily visible to the naked eye. Through binoculars, however, you'll see an elliptical glow (the galaxy's bright nucleus), which appears larger in small telescopes.



Now that I've introduced you to some of the constellations, it's time to head out and make your own friends. The expansive night sky will become more familiar to you after spending quality time learning the "faces" of the constellations. Class dismissed!

Craig Weatherwax, founder of OPT and purveyor of fine telescopes and accessories.

optcorp.com

Get what you want, when you want it!

adirondack video astronomy apogee inc apogee instruments astro systems astronomik astropier astrozap ats bob's knobs bogen brunton canon celestron coronado delkin denkmeier dewbusters diffraction limited discovery telescopes finger lakes instruments fujinon guan sheng hap cables helix hutech images plus intrinsics jmi k b systems ken press kendrick konus leica lightwedge losmandy lumicon main sequence meade mitty evolutionary wedges mountain instruments new astronomy press nikon on-point lasers optec orion parallax instruments pentax peterson engineering rc optical rigel sac sbig scopestuff scopetronix sirius tech skypieces sky spot software bisque solarscope space.com spaceshots spherical concepts starbound startek takahashi tech 2000 tele vue telrad universal astronomics vixen william optics

OPT

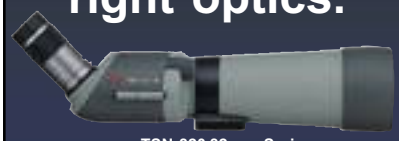
expertise, convenience, selection, price

Oceanside Photo & Telescope t: 800.483.6287

HIGH LANDER

Dynamic Viewing

From the sky to your backyard Kowa has the right optics.



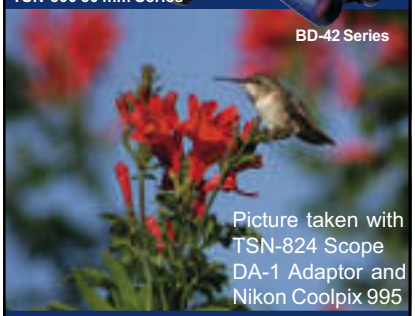
TSN-820 82 mm Series

BD-25 Series

TSN-660 66 mm Series

TSN-600 60 mm Series

TSN-500 50 mm Series



BD-42 Series

Picture taken with TSN-824 Scope DA-1 Adaptor and Nikon Coolpix 995

For a Retailer Near You Call,

(800)-966-5692

www.kowa.com

Kowa

Kowa Company, Ltd.
Kowa Optimed, Inc.

SUNSPOTTER®

THE SAFER SOLAR TELESCOPE

Learning Technologies, Inc.
40 Cameron Avenue • Somerville, MA 02144
Tel: 800-537-8703 • Fax: 617-628-8606
E-mail: sunspotter@starlab.com • www.starlab.com

Coronado
Solar Filters & Telescopes

Solar Electricity for Homes, Cabins, Campers, Observatories

$4 Catalog also has:
• Propane Refrigerators
• Solar Cookers
• Waterless Composting Toilets

12 volt:
Lights, Fans, Pumps, Motors, Bed Warmers

Kansas Wind Power - AE5
13569 - 214th Road, Holton, KS 66436
Phone 785-364-4407 Since 1975
www.KansasWindpower.net

Anyone can sell you a telescope.

We'll sell you the *right* telescope.

It takes more than a department store clerk with a price list and a wild guess to help you pick the right telescope. It takes experience. It takes people who actually use the telescopes and accessories they sell.

At ***astronomics***, we have that experience. We've been selling telescopes for over 25 years. Some of us have used scopes far longer than that. From the more than 200 different telescopes we carry, at prices from $249 to $200,000, we can help you pick the telescope that fits your needs . . . *and your budget.* Meade, Celestron, TeleVue, Takahashi, Questar, TMB, Discovery, Vixen, and more – we have *all* the good stuff. No hard sell. No guesswork. Just honest advice . . . and good prices.

Check out our informative website – or call us toll-free at the number below for our free Catalog XU. It has 8 pages of useful information on how to pick the right telescope, plus your discount prices on the more than 200 different telescope models and more than 1200 different accessories we carry . . . all at savings of up to 50%. The call will take only a minute of your time . . . but it will be a minute very well spent.

astronomics

Our 26th year of friendly service, good advice, and money-saving prices.

680 24th Avenue SW, Norman, OK 73069
(800) 422-7876 www.astronomics.com
FAX: (405) 447-3337 E-Mail: questions@astronomics.com
Visa, Mastercard, American Express, Discover
Phone hours: 9 to 9 CST Mon - Fri, 12 to 5 Sat. U. S. sales only.
Restocking fees apply to returns for credit and to merchandise returned in used or damaged condition.

Your guide to go-t

SINCE THE INVENTION OF THE TELEscope, manufacturers have been striving to improve every aspect of this fine instrument. They learned that size and mobility are key issues in deciding how useful a telescope is. Great steps were taken to develop mounts so telescopes could be moved easily along the known paths of stars and planets. Dual-axis mounts, gears, clock drives, and motors were all part of this evolution. Then, the invention of computers helped move large telescopes to a new level of complication. Amateur astronomy benefited from microprocessor technology, which reduced the size of computers while increasing their power. This technology has ushered in the era of the "go-to" telescope mount.

Basically, a go-to mount has three elements: the microprocessor, encoders, and motors. The encoders tell the microprocessor the physical position of the mount (and thus the telescope attached to it) in relation to a set point. The microprocessor then inputs that information into a program that tells the motors what to do as each command is entered, such as, "go to Saturn." The motors then move the telescope into the position Saturn is known to occupy in the sky at that given moment. Ah, the wonder of computers and how they enrich our lives. Of course, these three elements are incorporated into telescopes in different ways: They can be added on, integrated into the mount, or interfaced through a control paddle.

The latest generation of go-to telescopes incorporates global positioning system (GPS) receivers and electronic compasses that pinpoint a scope's exact location on Earth. Many go-to drives also determine the exact date and time. Some even figure out if a telescope is level and, if not, they apply a correction. After all this, the alignment

o scopes

Computerized astronomy is here to stay, and we've got the lowdown on drives that use microprocessors to guide you through the sky. /// BY MIKE MARCOTTE

process begins. The operator still needs to center alignment stars in the eyepiece to ensure proper setup, but that too may change someday.

Another wonderful advantage to computerized telescopes is that planetarium software and a personal computer can be used to operate most of them. Some even can be operated remotely via the Internet. For amateur astronomers, the bottom line is that with a go-to scope, they can spend more time observing objects and less time trying to locate them. The bottom line for telescope makers is that go-to scopes generate more sales to beginners and others who want to be sure they have their desired objects in the field of view.

The objective of this article is not to review different go-to telescopes, but rather to look at what's available. The proliferation of these scopes is staggering, and the sheer numbers make it impossible to include all the go-to telescopes and manufacturers here. With that said, let's start with the two giants of the telescope industry: Meade and Celestron. These two companies account for the majority of telescope sales worldwide. Celestron and Meade each offer a variety of telescope types and sizes, with the majority having go-to capabilities. At this time, these two companies are also the only ones offering built-in GPS receivers.

Meade

Meade Instrument Corporation's huge selection of go-to telescopes uses four main types of computerized mounts and hand controllers. These consist of the #494 Autostar Computer Controller, the #497 Autostar Computer Controller, the Autostar II control system for the LX200GPS-SMT, and the #1697 Computer Drive System.

The #494 Autostar Computer Controller works with the DS series of telescopes and the ETX-70AT. It has a database of 1,500 objects, capacity for 200 user-defined objects, and 9-speed dual-axis operation. Meade's StarNavigator sky software allows you to hook up your PC with an optional #506 Connector Cable Set and go to any object on the PC display with a mouse click.

The DS series consists of three telescopes — all on single tine, alt-azimuth mounts: the DS-2070AT, a 2.8-inch (70mm) f/10 refractor; the DS-2114ATS, a 4.5-inch (114mm) f/8.8 Newtonian reflector; and the DS-2130ATS, a 5-inch (127mm) f/7.9 Newtonian reflector. The other telescope that uses the #494 Autostar is the ETX-70AT, a 2.8-inch (70mm) f/5 refractor. This telescope is on a sturdy ABS fork mount that allows for either tripod or tabletop use.

The #1697 Computer Drive System runs Meade's 4-inch (102 ED), 5-inch (127 ED), 6-inch (152 ED), and 7-inch (178 ED) apochromatic refractors mounted on the LXD 650 and LXD 750 equatorial mounts. This system is used with the dual-axis DC-servo-motor-controlled drive, which is available for the LXD 650 and LXD 750 mounts. The keypad controller resembles the Autostar but has a 64,359-object library, 9 high-torque dual-axis drive speeds for photo-guiding corrections, and fast-slewing of the telescope across the sky at any speed from 3° per second to 8° per second, adjustable in 1° per second increments. The control panel includes an RS-232 interface for personal computers, an optional electric focuser, and a north/south switch for telescope operation anywhere in the world.

Mike Marcotte *is a retired firefighter and dedicated go-to telescope user who lives in El Paso, Texas.*

The #497 Autostar Computer Controller is used with the ETX-90AT, ETX-105AT, ETX-125AT, LX90, and the equatorially mounted LXD55 series. This Autostar has a database of more than 30,000 objects and capacity for 200 user-defined objects. In addition, it can go to any object for which you have coordinates. You also can use a computer running planetarium software to operate the telescope's go-to system.

The ETX-AT models of this group employ the Maksutov-Cassegrain optical design. The ETX-90AT has a 3.5-inch (90mm) aperture at f/13.8. The ETX-105AT has a 4.13-inch (105mm) aperture at f/14. The ETX-125AT has a 5-inch (127mm) aperture and operates at f/15. All these models come with the #884 Deluxe Field Tripod and can be used in either alt-azimuth or equatorial mode. They also can be used without a tripod on any level surface, such as a tabletop.

The Meade LXD55 series consists of six models that use the Autostar control system: three Schmidt-Newtonians, two achromatic refractors, and one Schmidt-Cassegrain, all mounted on the LXD55 German equatorial mount. All LXD55-series telescopes use a quick-release cradle-ring assembly, so the optical tubes can be removed easily from the mounts for transport.

The three Schmidt-Newtonians are the SN-6, a 6-inch (152mm) f/5; the SN-8, an 8-inch (203mm) f/4; and the SN-10, a 10-inch (254mm) f/4. The two achromatic refractors are the AR-5, a 5-inch (127mm) f/9, and the AR-6, a 6-inch (152mm) f/8. The lone Schmidt-Cassegrain in this series is the SC-8, which has the same tube as the LX200 but mounted on the LXD55 mount.

The other telescope that uses the #497 Autostar Controller is the LX90. The 8-inch

Meade Autostar II Computer Controller

Celestron NexStar 60GT

Meade LX200GPS-SMT

LX200 panel detail

f/10 Schmidt-Cassegrain optical tube is identical to the tube on the LX200, but the mount is similar to the ETX-AT models. This gives the scope the larger optics of the LX200 but the better portability of the smaller ETX-AT models.

At the top end of the telescopes offered by Meade is the LX200GPS-SMT series. These telescopes are all controlled by the Autostar II, which has a database of 145,000 objects; a 200-object user-defined library; and times and dates of sunrise/sunset, moonrise/moonset, Moon phases, meteor showers, equinoxes and solstices, to name just a few of the menu functions. Also included are timers, alarm functions, a red-LED utility light, and a low-battery warning alarm. The Autostar II also features 2,000 custom tracking rates, including sidereal and lunar modes, plus 7 alignment modes and an integrated GPS receiver. This series of telescopes comes in aperture sizes of 7-inch, 8-inch, 10-inch, 12-inch, 14-inch, and 16-inch. All these scopes use the Schmidt-Cassegrain optical design, except for the 7-inch, which is a Maksutov-Cassegrain. Other features of these scopes include a primary mirror lock, heavy-duty fork mounts, and Smart Mount, which enables your telescope to correct for systematic pointing errors, regardless of the cause.

Celestron

Celestron's entry-level go-to telescope line is the NexStar GT series. This telescope line is characterized by a single-arm, motorized, alt-azimuth mount. This series, which uses a NexStar Computerized Hand Controller with a database of 4,000 objects, consists of five telescopes: the NexStar 60GT, a 2.4-inch (60mm) f/12 refractor; the NexStar 80GT, a 3.1-inch (80mm) f/5 refractor; the NexStar

114GT, a 4.5-inch (114mm) f/9 Newtonian reflector; the NexStar 130GT, a 5-inch (130mm) f/5 Newtonian reflector; and the NexStar 4GT, a 4-inch (102mm) f/13 Maksutov-Cassegrain. This last scope is somewhat different from the others because of its more complex Maksutov-Cassegrain design. The design of the base and mount makes it more stable, so this telescope can sit securely on any flat surface or be mounted on a tripod. The arm also has a built-in holder for the hand controller.

The Celestron Advanced Series comes in refractor, reflector, and Schmidt-Cassegrain models. All these scopes are mounted on Celestron's CG-5 German equatorial mount. The go-to models of this series also use the NexStar Computerized Hand Controller but feature a 40,000-object database with room for hundreds of user-defined objects. The "quick-align" feature allows observers to set up the tracking mode without having to do a two-star alignment. A full menu of features provides for various safety functions, such as cord wrap and slew limits. The available go-to models in the Advanced Series are the C5-SGT, a 5-inch (127mm) f/10 Schmidt-Cassegrain; the C6-RGT, a 6-inch (150mm) f/8 refractor; the C8-SGT, an 8-inch (203mm) f/10 Schmidt-Cassegrain; the C8-NGT, an 8-inch (200mm) f/5 Newtonian reflector; the C9¼-SGT, a 9¼-inch (235mm) f/10 Schmidt-Cassegrain; and the C10-NGT, a 10-inch (254mm) f/4.7 Newtonian reflector.

An intriguing offering by Celestron is the NexStar "i" series. This series consists of only two Schmidt-Cassegrain telescopes: the NexStar 5i, a 5-inch (127mm) f/10; and the NexStar 8i, an 8-inch (203mm) f/10. In their standard configurations, these two scopes are not go-to systems, but the "i" series is

designed to be fully upgradeable. By adding the optional NexStar Computerized Hand Controller, both of these telescopes can become full go-to instruments. If you wish to upgrade even further, you can empower either telescope with GPS capability by adding the CN-16 GPS plug-in accessory. The CN-16 GPS accessory also can be used with the go-to scopes of the Celestron Advanced Series.

Jumping to what might be considered the flagship series of Celestron, we come to the NexStar GPS series: the NexStar 8GPS, NexStar 9¼GPS, and the NexStar 11GPS, all of which contain full go-to capabilities and a GPS receiver that fully automates the date, time, and location. With this information, the telescope will find true north, correct any leveling issues, and then start the alignment process. The NexStar Computerized Hand Controller is standard on these models. These telescopes are, as the numbers indicate, 8-inch (203mm), 9¼-inch (235mm), and 11-inch (279mm) scopes. All are f/10 Schmidt-Cassegrain models. The NexStar 8GPS and 11GPS models also are compatible with Celestron's Fastar Lens Assembly. This system allows you to replace the secondary mirror, which is attached to the front corrector lens, with the optional Fastar Lens Assembly and a CCD camera. With this setup in place, your NexStar is transformed into an ultra-fast, wide-field, f/2 imaging system. To observe visually with your NexStar, just reverse this procedure.

Celestron's newest series of go-to scopes is the CGE series. This series consists of observatory-class Schmidt-Cassegrain telescopes that come in 8-inch (203mm), 9¼-inch (235mm), 11-inch (279mm) and 14-inch (356mm) apertures, which are known as the CGE 800, CGE 925, CGE 1100, and

Vixen Star Book Controller

Vixen SPHINX mount

/// CONTACT INFORMATION

Astro-Physics
11250 Forest Hills Road
Rockford, IL 61115
[t] 815.282.1513
[w] www.astro-physics.com

Celestron International
2835 Columbia Street
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

Meade Instruments Corporation
6001 Oak Canyon
Irvine, CA 92618
[t] 800.626.3233
[w] www.meade.com

NightSky Telescopes
61432 Daspit Road
Lacombe, LA 70445
[t] 985.882.9269
[w] www.nightskyscopes.com

Obsession Telescopes
P.O. Box 804W
Lake Mills, WI 53551
[t] 920.648.2328
[w] www.globaldialog.com/obsessiontscp

SkyGear Telescopes
11910 W. 92 Street
Lenexa, KS 66215
[t] 913.707.5507
[w] www.skygeartelescopes.com

Starmaster Portable Telescopes
2160 Birch Road
Arcadia, KS 66711
[t] 620.638.4743
[w] www.starmastertelescopes.com

Takahashi
3110 S. Shepherd Drive
Houston, TX 77098
[t] 713.529.3551
[w] www.takahashiamerica.com

Vixen North America
32 Elkay Drive
Chester, NY 10918
[t] 845.469.8660
[w] www.vixenamerica.com

CGE 1400. Each of these telescopes comes mounted on the CGE go-to German equatorial mount. The Celestron CGE telescopes use the same tubes as the 8GPS, 9¼GPS, and 11GPS telescopes, while the CGE 1400 uses the C14 optical-tube assembly. All these scopes use the NexStar Computerized Hand Controller and are compatible with Celestron's CN-16 GPS accessory. The 8-inch, 11-inch, and 14-inch models are Fastar compatible.

As you can see, both Celestron and Meade have huge selections of telescopes for everyone, from the beginning amateur to the lifelong hobbyist. But although these two companies dominate the telescope market, lots of other companies offer computerized go-to mounts for telescopes.

Vixen

As of this writing, the newest go-to telescope drive comes from Vixen North America. The Vixen SX, or SPHINX, mount with the SX-HAL110 heavy-duty aluminum tripod can handle a 22-pound (13.5-kilogram) load. The SPHINX mount is a perfect complement to Vixen's 8-inch VC200L catadioptric telescope.

Go-to capability comes to the SPHINX mount with the addition of the Star Book hand controller. The Star Book liquid-crystal display screen measures 4.7 inches diagonally, and its zoom buttons allow quick target acquisition. In all, 22,725 objects are stored in its database.

Dobsonian go-to scopes

Another type of go-to system is the truss-tube Newtonian telescope. John Dobson's "Dobsonian" mount for the Newtonian telescope made them portable. Once "Dobs" became popular, the ability to locate and

/// TIPS ON ALIGNING A GO-TO TELESCOPE

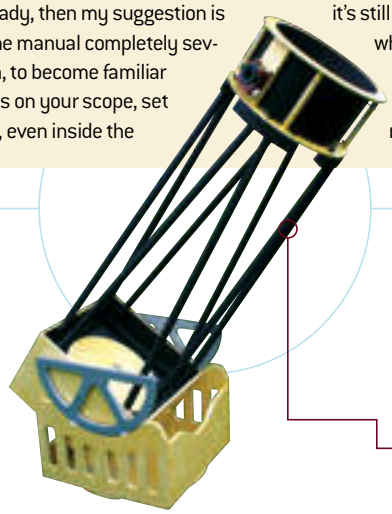
In the search for a first telescope, many "newbies" to amateur astronomy have been tempted to buy a computerized telescope, which has the allure of operational ease and speed. Unfortunately, some who have taken that step are left with less than satisfying results. The one thing beginning observers seem to overlook is that effectively using the computer on these telescopes requires some experience and practice. A basic knowledge of astronomy — including finding true north, knowing how to find key constellations and guide stars, and understanding how the apparent motion of the sky moves objects from east to west — is a must. Having a bit of knowledge in these areas can greatly simplify telescope use. Even telescopes with global positioning systems (GPS) often leave newbies flustered. My suggestion to those who would like to purchase a go-to telescope is to learn the basics of how a telescope works (in relation to the sky) by either spending some quality time with an experienced telescope owner or investing in a basic, manually operated telescope first.

If neither of these options appeals to you because your new go-to scope is sitting in your living room already, then my suggestion is that you read the manual completely several times. Then, to become familiar with the controls on your scope, set it up in daylight, even inside the house if you have room. As you read the instructions, learn and practice the procedures for each function, especially alignment. Schedule several of these practice sessions — trust me, you can't practice too much.

When you feel comfortable enough to set the telescope up for a real observing session, pick a location that has a fairly clear, level spot with as few obstructions as possible. For the drive to acquire and track celestial objects accurately, it must be level. Also, in order to align a telescope without GPS, you need to know the location's coordinates (longitude and latitude) and the exact time. Most go-to systems will give you a list of cities with coordinates to choose from, but if you observe outside a city, you'll need the coordinates of your location to maximize the accuracy of the drive. Always get to the observing site with plenty of daylight left to set up your scope properly. I like to be on location at least an hour before sunset. Remember that once it gets dark, everything is going to be ten times harder — fifty times harder if you haven't practiced.

Once you've set up the scope, make sure to align the finder scope with the main scope while it's still light out. Why align the finder scope when you have a computerized go-to system? If the telescope's drive doesn't center the object (for whatever reason), often it's just outside the eyepiece's field of view. A quick look through the finder scope will help you locate the object for re-centering. Finder scopes usually are small-aperture instruments, so I try to select bright objects as the first targets of my viewing session. To align your finder scope, choose a stationary object on Earth as far away as possible.

When the stars appear, proceed with the telescope drive's two-star alignment process. While you're learning (say, the first five or ten times), use your lowest magnification eyepiece to ensure you get the alignment stars in the field of view. Increase the magnification as you get more experience. Because most telescopes do not track while you're aligning, quickly center the star, and then move to the next step. It's been my experience that allowing the scope to remain on the last alignment star for a minute before using the go-to function seems to help the scope stay in alignment better. If, after aligning the telescope, it's still having problems locating objects, double-check that you entered the right date, time, and location, and then repeat the alignment procedure. It's embarrassing to realize the telescope is not aligning properly because you forgot to turn off the daylight saving time option or didn't set the date correctly in the first place. Remember, go slow, then go-to.



Obsession 18-inch Dobsonian reflector

SkyGear 16-inch Dobsonian reflector

track objects across the sky via go-to drives was not far behind.

Several companies currently produce a truss-tube Newtonian telescope with go-to capabilities. One of the first companies to expand the "truss Dob" telescopes into the go-to realm was Starmaster Telescopes. Starting with the Sky Commander Digital Setting Circles system, Starmaster developed its SkyTracker Go-To-Then-Track drive system. Starmaster will install this option on all its truss-design Dobsonian telescopes, which have apertures of 11 inches, 14.5 inches, 18 inches, 20 inches, 24 inches, and 28 inches.

Obsession Telescopes, the largest seller of truss Dob scopes, offers a go-to system on its 12.5-inch, 15-inch, 18-inch, 20-inch, and two of its 25-inch telescope models. Obsession uses the Argo Navis Digital Setting Circles (DSC) system combined with the Servocat Go-to Tracking Drive. This system includes a 29,000-object database, spiral search, and slip return that allows the observer to come back to an object when the telescope has been accidentally bumped or moved.

SkyGear Telescopes is another truss Dob telescope maker that uses the Servocat Go-to Tracking Drive. SkyGear gives you the option of using this drive with either the Argo Navis DSC or the Sky Commander setting circles and offers either system on their 12.5-inch, 16-inch, 20-inch, and 24-inch TravelScopes. SkyGear's cabinetry is CNC (computerized numerical control) machined to a high tolerance. This level of precision facilitates better go-to movement due to the accurate geometry of the mount.

One company offering truss Dob telescopes with the Servocat System combined with either the Argo Navis DSC or Sky Commander setting circles is NightSky

Telescopes, which offers scopes in the 12.5-inch to 22-inch range.

Only the mount, please

Another class of go-to drives involves only the mount. In other words, various types of telescope optical tubes can be mounted to complete the system. One popular go-to system is made by Astro-Physics. Their GTOCP3 Control Box and Computer Keypad provides go-to operation for the company's 400GTO, 600EGTO, 900GTO and 1200GTO mounts, each of which has high-quality, DC-servo-motor-drive electronics. These mounts can be operated either with the GTO handheld computer keypad alone or with various popular computer software packages.

Takahashi also offers several mounts that have go-to capacity: the EM-10 TPC Jr., the EM-200 TPC Jr., the EM-200 TPC, and the EM-500 TPC. All of these are high-end mounts for the serious amateur.

After-market go-to

I'd like to mention a few odds and ends before we wrap up. GoTo and Tracking Systems, a company that can be found on the Internet at *www.gototelescopes.com*, will install a go-to system on almost any telescope. Another telescope after-market company is Digital Astronomy, located on-line at *www.digitalastronomy.com*. Digital Astronomy offers many accessories for telescopes, including a plug-in GPS system for Meade go-to telescopes.

Believe it or not, the world of computer-controlled, go-to telescopes is just beginning to blossom. If the past is any indicator, the future is sure to be a fast-paced race for telescope innovations. A

The ABCs of obs

Sharpen your scope skills with these 26 tips. /// BY MICHAEL E. BAKICH

Amateur astronomy is about observing: Each and every time you look through an eyepiece, you make contact with a distant part of the universe. I've assembled this list of observing tips — one for each letter of the alphabet — to help you get the most out of those precious moments behind the eyepiece. I've discovered some of them on my own, but others were passed on to me by wise observing buddies. Read them, use them, and add to them. If you do, you'll become a better observer.

AVOID EYE FATIGUE. Take short breaks, and try one of these simple eye exercises every 20 minutes or so. Lightly cup your eyes with your palms and relax for 60 seconds. Or simply look away from the eyepiece and roll your eyes up, down, around, and side-to-side for 20 seconds; then relax, eyes closed, for another 30 seconds.

BATTERIES. Take the batteries you know you'll need — as well as the batteries you think you won't need.

CAMERA FOCUSING. Astrophotographers want their lenses focused at infinity, but newer auto-focus lenses can go past infinity when focused by hand. To resolve this problem, set the lens at infinity during the day and then lock it there with one or two wraps of tape around the barrel. Use tape that won't leave a residue (no duct tape). Manual focus lenses don't have this problem, but some astrophotographers tape them anyway. It's one less thing that can go wrong.

DARK ADAPTION is the process by which the eyes increase their sensitivity to low levels of illumination. In the first 30 minutes, sensitivity increases 10,000-fold, with little gain after that. But brief exposure to bright light temporarily rolls back this hard-won increase. Just how much dark adaption you lose depends a little on the intensity and a lot on the duration of the light. A single flash from a strobe does less damage than a bright light lasting a second or more. At night, your eyes are most sensitive to red light, which means that for a given brightness, you'll see more in light of this color. Use a red light, adjust its intensity to the lowest usable level, and then gaze only briefly at the illuminated object.

EYE PATCH. Wear an eye patch over your observing eye while setting up equipment. Put it on as long as possible before the start of your session, and you will be rewarded with a fully dark-adapted eye when you're ready to begin observing. Move the patch to your non-observing eye when you look through the eyepiece. This lets you keep both eyes open, a technique that reduces eye fatigue. (Skeptical? Try reading this story with one eye closed for 60 seconds.) Before checking charts with a light, move the patch over your observing eye.

FOCUS each time you put your eye to eyepiece and anytime you have a question about the sharpness of an image.

GOING DEEP. When you're observing objects at the limit of vision, or looking for small details in brighter ones, use a technique sometimes called "rocking the scope." Gently tap the mount or the telescope tube. It really helps faint details pop out!

HIGH-ALTITUDE OBSERVING results in a degree of hypoxia, or low oxygen in body tissues, that significantly alters low-light color perception. Most people notice visual changes when they travel to altitudes approximately 2,000 feet higher than where they live, although those living at or near sea level may not begin to notice such effects until they reach an altitude of 4,000 feet.

INTOXICATION. Don't drink and drive the telescope if you're looking to do some serious observing. Why? Alcohol impairs vision.

ALL ILLUSTRATIONS: *ASTRONOMY*: KELLIE JAEGER

erving

JUST IN CASE. Pack a "space blanket" with your equipment. Made from a metal-coated plastic film, it will trap body heat when wrapped around you, giving you an edge in all but the most severe weather conditions. It also shields against wind and rain, weighs just a few ounces, and only costs a few dollars. Often advertised as a "survival blanket," that's exactly what it may be for you.

KNOW YOUR EQUIPMENT. If you've added a new piece of equipment to your observing lineup, set it up at home first. Any problem revealed in the light will be one less you'll have to deal with in the dark. As a second step, set up in your yard and observe as if you were at your remote dark-sky site. It's surprising what a test-run like this will teach you.

LIMITING MAGNITUDE. No better gauge of observing-site quality exists than a direct measurement of limiting visual magnitude, or LM. Most observers determine their site's LM by identifying the faintest star they can see, usually near the zenith. Others use a method devised by meteor observers, who count the number of visible stars within predetermined asterisms. For more information on this method, refer to "Estimating Limiting Magnitude" on the Students for the Exploration and Development of Space web site, *www.seds.org/billa/lm/rjm.html*.

MOSQUITOES. I hate mosquitoes, and I'm willing to bet you do, too. Mosquitoes attack whomever is handiest, but they prefer adults to children, women to men, and pregnant women most. They're attracted to heat, carbon dioxide, and movement, so swatting at one is essentially an invitation to others. The most effective mosquito repellents contain DEET, the acronym for N, N-diethyl-meta-toluamide. Experts suggest treating clothing as well as exposed skin. Most fabrics are approximately 1 millimeter thick, but the average mosquito's proboscis is 2mm long. DEET won't keep a mosquito from approaching, but it can stop her from biting — the attacker *is* female — by jamming the insect's antennae cells that are sensitive to lactic acid.

NIGHTTIME SAFETY. If you must observe alone at a remote location, double-check everything before you leave — especially non-observing-related details, such as how much fuel is in your vehicle. Let someone know exactly where you will be and exactly how long you plan to be out, and then stick to the plan. Your life may depend on someone knowing where you are.

Michael E. Bakich *is an associate editor of* Astronomy.

OBSERVING CHAIRS AND LADDERS. If you're at all uncomfortable at the telescope, you'll do less observing, and the observations you make will be less fulfilling and less accurate. In my opinion, nothing says comfort like a high-quality observing chair. Such an accessory has four main features: sturdy construction; padded seat; easily adjustable height; and back support.

Observing chairs work fine for refractors and Schmidt-Cassegrain telescopes, which have eyepieces at the lower ends of their tubes. For large Dobsonian-mounted scopes, however, a ladder of some type is usually necessary. I suggest buying a three-step folding utility ladder with a tray. Such ladders usually feature wide, rubber-coated steps — a great safety feature after sunset — and the tray is a real bonus when you need to change eyepieces or filters.

POSITION OF TELESCOPE. When observing sessions go well into the morning hours, be sure to point your telescope where the Sun won't shine. This is a crucial tip if you're going to leave your scope uncovered, but remember that the Sun has been known to damage even telescopes that were capped.

QUESTION YOURSELF. Write a few questions on index cards before your observing session. For example, a card for planetary nebulae might have these questions on it: Can you see the central star? At what magnification? What shape is the nebula? Is any color apparent? And so on. Questions will jog your memory and remind you to look for certain common details — especially when you're tired and not necessarily at your peak.

RECORD OBSERVATIONS. I have maintained a detailed observing log for more than two decades. My instrument of choice is a digital (formerly tape) recorder. Many of my observing friends write out their observations either in a logbook or directly onto a star chart, a method that allows for sketches as well. I speak into my recorder at

the telescope and transcribe the observations later, usually the next day. If you follow this path, don't let your recordings pile up.

SITE SELECTION. Perhaps paradoxically, the finest skies on Earth are not the darkest. The more stars you're able to see, the brighter the overall sky appears. I have seen the Milky Way cast a shadow in truly dark locations. A site rated "excellent" has three characteristics: it's free of light pollution; it contains low amounts of aerosols (dust, air pollution, and water droplets); and it's at a relatively high altitude, between 5,000 feet (1.5 kilometers) and 8,000 feet (2.5 kilometers).

TUBE CURRENTS degrade telescopic images, but how do you know if you have a problem? Check the out-of-focus image of a fairly bright star. If you see lots of circular motion inside the star's image, you have a severe problem. The best solution is a small, low-flow fan to move warmer air out of the telescope tube and quickly bring your mirror to the same temperature as the ambient air.

UNIVERSAL TIME (UT). Use it! Memorize your time zone's UT correction both with and without daylight-saving time. Use UT in your observing log entries. Use it in your correspondence. Using UT is one way we all can standardize our observations.

VITAMIN A. A diet deficient in vitamin A can lead to impaired night vision. An adequate intake of Vitamin A from foods such as eggs, cheese, liver, carrots, and most green vegetables will help ensure proper visual acuity at night. Please note that excessive quantities of Vitamin A will not improve night vision *and* may be harmful to your health.

WEATHER AND SEEING. Some atmospheric factors indicate the quality of "seeing," or the steadiness of an astronomical image. An air mass colder than the ground will produce puffy cumulus clouds and unsteady air, but it's usually relatively free of dust. An air mass warmer than the ground will produce stratiform clouds, haze, or mist, and hold copious amounts of dust, but astronomical images

will be steadier. Bad seeing is almost guaranteed at least 24 hours following the passage of a front (the boundary between warm and cool air masses) or trough (an elongated area of low pressure). Seeing can be very good with thin cirrus clouds aloft, but the opposite is true when high cirrus clouds combine with low-level crosswinds.

X-TREME OBSERVING. Okay, it's a stretch, but few amateurs have X-ray telescopes. "X-treme" observing means viewing in cold weather. For low-temperature observing, preparation is everything. Over pack. The difference between life and death could hang on whether you brought along a single piece of gear.

Most heat loss occurs from the head, so keep yours warm. My personal headgear consists of a fleece pullover head cover topped by a wide-brimmed hat. Heat also will seep into the cold ground through your boots. I decided to purchase the warmest boots that would allow me to drive a vehicle.

Hand warmers are superb but never seem to last the full time specified on the package. Keep warmers in your side pockets. Slip them in and out of your gloves or mittens for quick warm-ups.

Finally, dress in layers. I generally wear fleece long underwear and thick pants. My upper body is covered with a T-shirt; a thin, long-sleeved, flannel shirt; a fleece pullover, and a down jacket. My wife, who is affected by the cold more than I am, wears a ski rescue suit as her outer layer. When fully zipped, with the hood up and boots and gloves in place, the wind has few places to chill her delicate frame.

YOUR OWN PACE. Some observers spend an hour or more on each object, trying to glean every bit of detail. Others take a leisurely pace of between five and fifteen objects per hour. Discover what works best for you.

ZOOM EYEPIECES. If you don't have the cash to fill a large fishing-tackle box with eyepieces, consider a high-quality zoom eyepiece. Such an accessory will provide you with a range of magnifications at a cost much less than the combined cost of each eyepiece within a single zoom's range of focal lengths.

See The Universe With Two Eyes!

Astronomy enthusiasts in over 30 countries have enjoyed Denkmeier Binoviewing Systems in a variety of telescope designs

Toll Free Order Line
(866)340-4578
www.denkmeier.com
DENKMEIER

Green Laser Pointer
points out the stars
www.betapointer.com
phone 800.546.2382

The Nature Place
For Nature & Astronomy Vacations, Reunions, & Conferences in Colorado.
www.thenatureplace.net
Tel: 719-748-3475

Astroscan®
An Ideal First Telescope For The Whole Family
$199
The original Astroscan is still the best choice available for beginners looking for a low-cost, easy-to-use telescope or for expert stargazers seeking a high performance portable scope.
Contact Us Today For A Free Catalog
Over 2,000 Items For Science Hobbyists!
Edmund Scientific's
SCIENTIFICS®
Dept. A041-C821
60 Pearce Ave. • Tonawanda, NY 14150
Phone: 800-728-6999
email: scientifics@edsci.com
www.scientificsonline.com

StarGPS
Plug & play GPS for Autostar, LX200, Gemini and more!
www.StarGPS.ca

EUROPE'S PREMIER WEBSITE
http://www.scsastro.co.uk
SCS ASTRO

Howie Glatter Introduces
The Self-Barlowed Laser Collimator
Barlow upgrade for Glatter holographic collimator $35
Complete Units Priced from $150
High Output green SkyPointer® $150
SkyFinder® Brackets* :
SCT $30
Red Dot $ 35
QuickFinder® $40
Plain $ 30
Other Brackets, Laser Collimators, and Binocular Filters Available
*SkyPointer not included with brackets
Howie Glatter 3850 Sedgwick Ave. Bronx, N.Y. 10463
Tel/Fax (718) 796 3203
www.skypointer.net www.collimator.com
e-mail: howieglatter@mindspring.com
Web Pages Revised and Expanded

www.z-bolt.com
Green Lasers for Star Pointing Star Finders
< 5 mW Green Laser Pointer—$69.00
Modified Green Beam Laser—$129.00
Enter *Astronomy Magazine* Code 532 at our Online Store. Receive 5% off ALL *Astronomy* Category Models!! Faxed PO's accepted for universities, corporations, government agencies, and the U.S. Armed Forces.
Beam of Light Technologies, Inc.
Toll Free: 877-801-9299 Fax: 603-309-6020

How do you make an easy-to-use telescope even easier?
The Landing Pad!
Where the best telescopes touch down!
For Celestron and Meade GPS scopes
www.starizona.com

TOLL FREE
800-221-0828
focus
camera, inc.
NEW YORK'S PREMIER PHOTOGRAPHY SOURCE FOR OVER 37 YEARS
Tel: 718-437-8810
Fax: 718-437-8811
orders@focuscamera.com

Specialists in Telescopes, Binoculars, Spotting Scopes Digital Cameras & Accessories

Fully Secure Ordering Online!
www.focuscamera.com
Over 25,000 Product Descriptions Online

- Explore our online telescope and binocular buying guide and ordering service, or call Toll-Free to order by phone
- Huge assortment of astronomy products **In Stock**, for **immediate delivery**
- **Meade Authorized Advanced Products** mail order dealer
- Serving customers honestly since 1965
- Celestron, TeleVue, Kowa, Bushnell/B&L, Fujinon, Leica, Swift, Zeiss, Canon, Nikon, Olympus, Fuji Digital & many others.

camcor, inc.™

One of the largest Selections!

- Telescopes
- Binoculars
- Eye Pieces
- Spotting Scopes
- Cases
- Tripods
- Accessories
- Cameras
- Film
- Maps
- Books
- Globes

And much more!

All Name Brands Available!

Bushnell • Canon • Celestron • Discovery • Fujinon • JMI
Kendrick • Kowa • Meade • Nikon • Pentax • Rigel
ScopeTronix • Steiner • Swarovski • Tele Vue • Thousand Oaks

800-868-2462

camera corner
Division of Camcor, Inc.
Since 1949

2273 South Church St. • Burlington, NC 27215
www.camcor.com e-mail:sky@camcor.com

Ideal for your home or office!

***Astronomy* Magazine presents:**

Deep Space Mysteries 2005 Calendar

Striking images of dramatic celestial observations include Spiral Galaxy NGC 3370, The Dumbbell Nebula, the Andromeda Galaxy, and many more. Features data on viewing many celestial events, a guide to choosing binoculars, and detailed descriptions composed by the staff of *Astronomy* Magazine. Recognizes national holidays. 13 x 10½.

Item #68139 • $11.99 • 0-89024-399-9

1-800-533-6644

Mon-Fri, 8:30am-5:00pm Central Time.
Outside the U.S. and Canada, call 262-796-8776
Fax 262-796-1615

Order online:
Astromagbooks.com

To order by mail: Send your order to Kalmbach Publishing Co. • Dept. A2006 • 21027 Crossroads Circle • Waukesha, WI 53187-0986

Include for shipping and handling:

Merchandise Total	Add for S&H
$15.00 or less	$4.95
$15.01-30.00	$5.50
$30.01-50.00	$6.50
$50.01-75.00	$7.50
Over $75.00	$8.50

Canada add an additional $2.00, other foreign add an additional $5.00. For Wisconsin delivery, add 5% sales tax to total; Pennsylvania add 6% sales tax to total. For delivery in Canada add 7% GST to total. Payable in U.S. funds. Prices and availability subject to change.

A2006

04X1152

Arizona's Complete Astronomy Shop

Stellar Vision
ASTRONOMY SHOP
In business since 1986

Telescopes, Microscopes, Binoculars, Books
CCD Systems, Star Charts, Accessories & More

New & pre-owned equipment
We service & repair equipment
Observatory construction & service and repair

Telescope and equipment rental's
Star-Tours, Custom work available
Rental House w/observatory
by the day, week, month.

Trade-ins welcome, phone orders welcome.
Credit cards accepted. We ship direct

Stellar Vision & Astronomy Science Shop
1835 S. Alvernon #206 • Tucson, AZ 85711
(520) 571-0877 • fax: (520) 571-0147
azstellarvision.com

Refracting Telescope Kit
Celestial Sphere Kit
Cardboard Spectrometer Kit
Holographic Diffraction Grating
PROJECT STAR
Learning Technologies, Inc.
40 Cameron Avenue • Somerville, MA 02144
Tel: 800-537-8703 • Fax: 617-628-8606
E-mail: starlab@starlab.com • www.starlab.com

SMARTASTRONOMY
ULTIMATE TRIPOD/TELESCOPE CASE
TELECOPE ACCESSORIES/CUSTOM CASES
www.SmartAstronomy.com

Telescopes.com
UP TO 50% off retail!
World's Largest Selection of Telescopes!
www.telescopes.com 1-800-303-5873

Join *Astronomy* magazine in Alaska for a
Northern Lights Tour
March 4-12, 2005

Chase the colorful curtains of the aurora borealis through Alaska's interior with *Astronomy* magazine. Along with catching one of the most spectacular views of the night sky, you will experience the magnificent vistas of a great, unspoiled wilderness.

Our experience begins in Chena Hot Springs, 60 miles from Fairbanks, and far from light pollution. The evening aurora should produce an impressive show as solar activity is expected to be high in March 2005. During the day you can take advantage of a horse-drawn sleigh ride, a dog sled ride and a sunset snow-monkey ride to the top of the mountain. Or relax in the world famous hot springs.

The adventure continues with three nights in downtown Fairbanks at the Springhill Suites Inn. You can arrange to shop, downhill ski, or simply curl up with a good book.

The breathtaking scenery is guaranteed to put you on sensory overload. Whatever your choices for the daylight and evening hours, pack your warm clothes and join an *Astronomy* editor on this watch for the magical northern lights in the heart of Alaska. See you there!

For more information call Specialty Tours today at:
1-800-677-9412 (US only) or 727-796-7555
Visit: a1specialtytours.com
E-mail: steves@a1specialtytours.com
Astronomy magazine

one million stars!
2sky™ Star Chart for Palm® handheld computers
get it today at:
2sky.org

SURPLUS SHED℠
SURPLUS OPTICS AND ELECTRONICS
FREE 80 PAGE CATALOG
Phone Toll Free:
1-877-7SURPLUS • 610-926-9226
E-Mail: SURPLUSHED@aol.com
www.SurplusShed.com
8408 Allentown Pike, Blandon, PA 19510

NO TOOLS!
$16 SHIPPED WORLDWIDE
Bob's Knobs
Easy Collimation for Meade & Celestron SCT
Macrow Technical Services
6976 Kempton Rd.
Centerville IN 47330 USA
765-855-5109
www.bobsknobs.com

DISCOVER
Kitt Peak
National Observatory
Tucson, AZ
Public Programs for Amateur Astronomers
• CCD Workshops
• Digital camera imaging
• CCD Imaging with our expert guides
• Astrophotography
• or just observe
520-318-8726
www.noao.edu

Think TRIFID

This thermo-electrically cooled camera downloads low noise, six mega-pixel images over USB in less than two seconds. Our drivers plus AIP4WIN, CCDSoft and Maxim/DL make astrophotography easier than you thought possible. With a low price and lifetime warrantee Trifid is the camera to own.

www.YankeeRobotics.com
Toll free 888.FOR.YANKEE
YANKEE ROBOTICS

The year's best astronomy books

Like black holes devouring stellar companions, many astronomy buffs attract books. These 22 books are good material to feed your own library's accretion disk. /// BY ROBERT BURNHAM

Astronomy and space exploration never sit still — and that holds true even in "book space." Since *Explore the Universe 2004* appeared, numerous excellent books on all areas of astronomy have hit print. Below is a personal selection of the best of them.

Fred Schaaf provides a month-by-month tour of the sky in ***A Year of the Stars*** (Prometheus Books, Amherst, New York, 2003). The topics include objects you can see with the naked eye and with telescopes. Two introductory chapters give beginners some basic orientation on the visible sky and astronomical objects. Because the book is arranged seasonally, you can pick it up and start any time of year.

Sky Vistas by Craig Crossen and Gerald Rhemann (Springer-Verlag, New York, 2004) is aimed at backyard observers using binoculars and small telescopes. Beautiful photos (color and black and white) in the book highlight star clusters, galaxies, and nebulae. Crossen also explains, in an easy-to-follow manner, some of the astrophysics that makes objects look the way they do. In much the same way, Charles A. Wood's ***The Modern Moon*** (Sky Publishing Corp., Cambridge, Massachusetts, 2003) provides a clearly illustrated lunar guidebook. His nicely achieved goal is to help anyone owning a telescope explore the Moon, region by region, with a geologically informed eye.

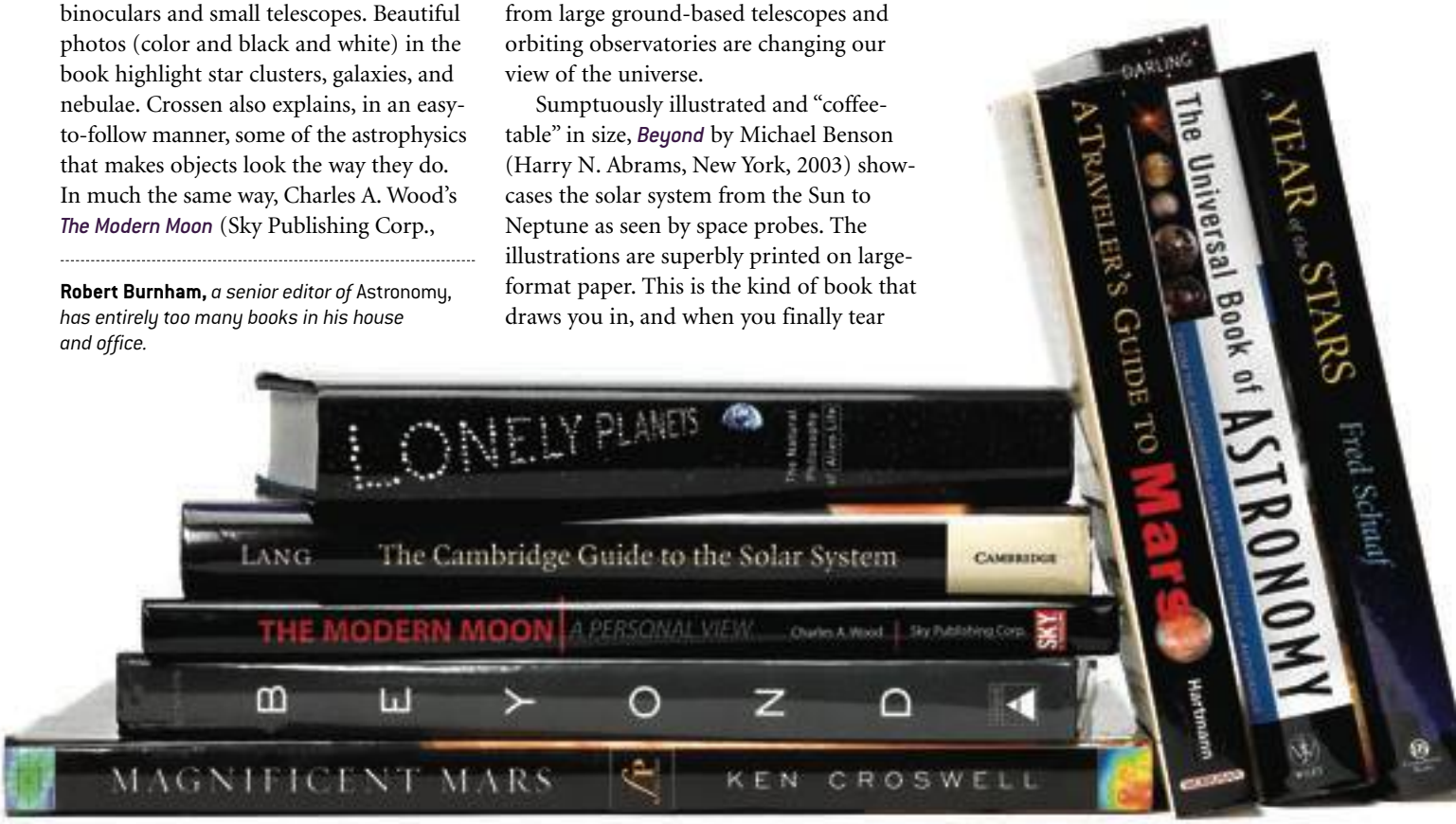
In ***Observing Variable Stars*** (Springer-Verlag, New York, 2003), Gerry Good takes observers on a tour of stellar instabilities, outlining all the major variations that stars undergo. (Some variations are accidents of viewing geometry seen from Earth.) Good also gives lots of helpful advice about techniques ranging from naked-eye viewing to using telescopes.

Visions of the Cosmos by Carolyn Collins Petersen and John C. Brandt (Cambridge University Press, New York, 2003) delves into the world of state-of-the-art astronomical imagery, exploring the way photos from large ground-based telescopes and orbiting observatories are changing our view of the universe.

Sumptuously illustrated and "coffee-table" in size, ***Beyond*** by Michael Benson (Harry N. Abrams, New York, 2003) showcases the solar system from the Sun to Neptune as seen by space probes. The illustrations are superbly printed on large-format paper. This is the kind of book that draws you in, and when you finally tear away, the everyday world looks different to you for a while.

Astronomical terms frequently confuse beginners, who usually need a lexicon that falls between a dictionary and an encyclopedia. Neatly located in a high-utility zone between these two approaches is David Darling's ***The Universal Book of Astronomy*** (John Wiley & Sons, Hoboken, New Jersey, 2004). Besides the readable A–Z entries, an appendix lists the entries under broad topics, such as astrobiology or stellar physics.

The Cambridge Guide to the Solar System by Kenneth R. Lang (Cambridge University Press, New York, 2003) presents the planetary family sans the Sun. Four sections cover basic principles, the terrestrial worlds, the gas giants, and "remnants of creation" (comets, meteoroids, asteroids).



Robert Burnham, *a senior editor of* Astronomy, *has entirely too many books in his house and office.*

For a close look at a much-neglected planet (the last spacecraft to visit was Mariner 10 in 1975), check out ***Exploring Mercury*** by Robert G. Strom and Ann L. Sprague (Springer-Verlag, New York, 2003), which gives a marvelously detailed overview. It comes with a CD-ROM containing a generous selection of Mariner 10 images and mosaics, plus the quadrangle maps from the *Atlas of Mercury* published by NASA in 1978.

The Red Planet has drawn much attention lately, and two works make a good pair for any armchair Marsonaut. ***Magnificent Mars*** by Ken Croswell (Free Press, New York, 2003) is a large-format work full of colorful photos that will stun anyone who flips through it. ***A Traveler's Guide to Mars*** by William K. Hartmann (Workman Publishing, New York, 2003) is a handy companion that tells the story of the planet Mars in an easily readable form.

Stepping farther from the Sun, ***The Orion Nebula*** by C. Robert O'Dell (Harvard University Press, Cambridge, Massachusetts, 2003) explores one of the most beautiful and popular deep-sky objects. Subtitled "where stars are born," the book uses the nebula as a springboard to talk about star and planet formation.

Planets orbiting other stars is the sole focus of ***New Worlds In the Cosmos*** by Michel Mayor and Pierre-Yves Frei (Cambridge University Press, New York, 2003). The authors describe the first extrasolar planetary systems discovered and how they differ from our own. The authors also explore what these systems tell us about the formation of stars and planets and the likelihood of life in the universe. (This book is a translation of a 2001 French publication.)

The Edge of Infinity by Fulvio Melia (Cambridge University Press, New York, 2003) looks at the role of supermassive black holes in the universe. Melia's story runs from the earliest period after the Big Bang (when black holes may have helped shape the structure of the universe) to the present day (when they are central engines in active galaxies and ordinary ones).

Dan Falk's ***The Universe on a T-Shirt*** (Arcade Publishing, New York, 2004) tells the fascinating story of philosophers and physicists, from antiquity to now, who have sought a simple formulation to explain all creation. Ideally, this "theory of everything" should be compact enough to go on the proverbial T-shirt. The search isn't yet successful — but physicists are closer today than they ever have been.

David Grinspoon pokes into the question of what alien life might be like and how we could spot it from afar in ***Lonely Planets*** (Ecco Press, New York, 2003). What's his telltale sign? He'd look for a planet with an atmosphere out of chemical balance with a planet's surface materials. That, he says, would tell us that *something* is going on there. ***Life in the Solar System and Beyond*** by Barrie W. Jones (Springer-Verlag, New York, 2004) looks at the chances we have for finding life on each of the Sun's planets and moons. Then, Jones explores how astronomers are carrying out the search for life elsewhere in the universe.

It's sometimes said that Nicolaus Copernicus's great work *De revolutionibus* was ***The Book Nobody Read*** (Walker & Company, New York, 2004). Nonsense, says Owen Gingerich, who tracked down more than six hundred surviving copies of the book. Gingerich tells an absorbing story of a decades-long hunt during which he uncovered interesting and perceptive comments written into the margins of many copies. Copernicus, it seems, did not lack for knowledgeable readers, and his work began to influence astronomers from the outset.

Do you know a star-struck youngster? If so, Robin Scagell's ***Children's Night Sky Atlas*** (DK Publishing, New York, 2004) would make a colorful and absorbing gift for kids ages 9–12. Combining star maps, beautiful astronomical photos, and history, it will feed any child's imagination. For the same age group, ***Exploring Saturn*** by Dan Bortolotti (Firefly Books, Toronto, 2003) makes a good companion for the ongoing Cassini mission to the ringed planet.

Space missions form the entire focus of ***The Cambridge Encyclopedia of Space*** by Fernand Verger et al. (Cambridge University Press, New York, 2003). Thirteen chapters cover everything from the basic celestial mechanics of orbits, to space hardware, to manned exploration, past and future. The book also includes an extensive index.

Finally, a sobering caution from the recent past, ***Comm Check . . .*** by Michael Cabbage and William Harwood (Free Press, New York, 2004), tells the story of the space shuttle Columbia's last flight. More than just a sad and gripping narrative, it delves into the management and engineering failures that produced the disaster — and their parallels with similar failures in 1986 that led to the destruction of the shuttle Challenger. A

ASTRONOMY: WILLIAM ZOBACK

INDEX *of* ADVERTISERS

2Sky 89
Astronomics 73
Astronomy Calendar 88
Astronomy Magazine 35
Astronomy.com 93
Atomic Time 27
Beam of Light Technologies 87
Beta Electronics 87
Binoculars.com 89
Bob's Knobs 89
Camcor, Inc. 88
Celestron 2
Denkmeier Optical 87
Efstonscience, Inc. 27
Focus Camera 88
Glatter, Howard 87
KB Systems 27
Kansas Wind Power 73
Kitt Peak National Observatory 89
Kowa Optimed, Inc. 73
Learning Technologies 27, 73, 89
Lumicon 3
Meade Instruments Corp. 108
Nature Place, The 87
Oceanside Photo & Telescope 72
Orion Telescopes & Binoculars 107
Pixsoft, Inc. 87
SAC Imaging Systems 27
SCS Astro 87
Scientifics 87
ScopeTronix 34
Smartcase Designs 89
Starizona 87
Stellar Vision 89
Surplus Shed 89
Swinburne University of Technology 27
Website Directory 92
Yankee Robotics 89

Web Site Directory

Check out these businesses... They're only a click away!

ANDROMEDA SOFTWARE INC.
Complete Online Catalog
andromedasoftware.com
Hard-to-find Astronomy & Science Software for Windows & Mac Since 1985

NEW MEXICO ASTRONOMICAL
Telescope Specialists
www.nmastronomical.com
Before you buy, try our telescopes at night. Largest display of telescopes in NM. (505) 720-5666

ASTROZAP
astrozap@yahoo.com
www.astrozap.com
Your #1 source of dew prevention shields on the planet. Hundreds in stock! Dew it in style!

OWL SERVICES
owl1@owlservices.com
www.owlservices.com
Special prices on Knight Owl Eyepieces
Telescopes • Binoculars!
FREE # 1-888-OWL-WARE
10-6 EST M-F

DIGITEC OPTICAL
Digitec@optonline.net
www.digitecoptical.com
Telescopes, Accessories, CCD Cameras, Camera Adapters
MEADE CLESTRON KONUS LOMO SAC & MORE
1-888-327-5759

RIVERS CAMERA SHOP
sales@riverscamera.com
riverscamera.com
Large inventory. Meade, Celestron, Televue, Thousand Oaks, Kendrick, Apogee, Canon, Pentax.

EFSTONSCIENCE
sales@telescopes.ca
www.telescopes.ca
Science & Astronomy SuperStore. Canada's best prices and selection serving observing since 1970.

SPACE: FRONTIER OF THE MIND
To order, please contact:
www.amazon.com or visit
www.auerspace.com or email
aueruniverse@sympatico.ca
Biographies of great astronomers, from 700 B.C.–2000 A.D., with ca. 450 pgs. of text and 100 pgs. of color diagrams.

KHAN SCOPE CENTRE
info@khanscope.com
www.khanscope.com
New, used. Free newsletter.
3243 Dufferin St.
Toronto-Ontario, Canada

For advertising information call Ken Kozerski at:
888-588-1544
ext. 636

Get MORE from ASTRONOMY.COM!

Now offering exclusive access to subscribers and newsstand buyers:

- Premium online content
- Customized, interactive star maps, and weather
- Full information on this month's sky events
- Massive multimedia archive
- Aurorae alerts
- Bonus in-depth news material
- Enormous archive of information on hobby astronomy

Astronomy.com

Visit the new Astronomy.com

Experience the new universe on the Internet. There's nothing else like it.

04X1106

Venturing into the beautiful. uni

SOLAR PROMINENCES AND FLARES are easiest to see when viewed through a hydrogen-alpha (Hα) filter. Such a filter blocks out most of the light from the Sun, allowing only a small fraction — that with a wavelength of 655.28 nanometers — through. Observers who use Hα filters visually often see prominences and flares slowly changing as they watch, and some can be quite large. For example, the tree-shaped prominence erupting from the edge of the Sun on the right of this image is several times as large as Earth. (7-inch Meade apochromatic refractor, Coronado Technology Group 90mm hydrogen-alpha filter, Pictor 1616XTE CCD camera, taken January 5, 2004, from Chiefland, Florida) /// **JACK B. NEWTON**

verse

Top, **COMET LINEAR C/2002 T7** (7-inch Meade apochromatic refractor at f/9, Finger Lakes Dream Machine CCD camera, LRGB image with a 2-minute exposure in each color, taken February 13, 2004, from Portal, Arizona) /// **JACK B. NEWTON**

Above, **LUNAR CRATER ALIACENSUS** (6-inch Fraunhofer achromatic refractor, Sony TRV740E videocamera, composite of 380 frames, taken September 18, 2003, from Wittern, Netherlands) /// **RALF VANDEBERGH**

Right, **CONSTELLATIONS OF THE AUTUMN SKY — AURIGA AND PERSEUS** (Pentax 67 6x7 medium-format camera on a motorized, equatorial mount, 90mm lens at f/4, Kodak PPF 120 format film) /// **JOHN CHUMACK**

Top, **THE GREEN FLASH** (10-inch Meade Schmidt-Cassegrain telescope at f/10, 35mm camera, Kodak Elite 100 film, 1/125-second exposure, taken February 17, 1998, near Ragusa, Sicily) /// **GIANNI TUMINO AND MELANIA PLUCHINOTTA**

Above, **THE CRAB NEBULA (M1)** (20-inch RC Optical Systems Ritchey-Chrétien telescope, Finger Lakes Instruments IMG6303E CCD camera, LRGB image with exposures of 60, 20, 20, and 20 minutes, respectively) /// **BRIAN LULA**

Right, **REFLECTION NEBULA IC 348 IN PERSEUS** (6-inch Astro-Physics refractor at f/7, 6x7 camera, hypersensitized Kodak 120 format PPF Pro 400 film, two 60-minute exposures digitally combined) /// **GEORGE GREANEY**

Top, **THE INTEGRAL SIGN GALAXY (UGC 3697)** (16-inch RC Optical Systems telescope at f/8, ST-10XME CCD camera, LRGB image with exposures of 60, 20, 20, and 20 minutes, respectively) /// **BONNIE FISHER, MIKE SHADE AND ADAM BLOCK**

Above, **JUPITER** (11-inch Celestron SCT at f/31, ATK-1HS CCD camera, taken March 1, 2004, at 22h01m UT (left); March 1, 2004, at 23h04m UT (center); and March 17, 2004, at 23h51m UT (right), from South Buckinghamshire, England) /// **DAMIAN PEACH**

Right, **GLOBULAR CLUSTER OMEGA CENTAURI (NGC 5139)** (6-inch Astro-Physics 155EDF refractor, SBIG ST-10E CCD camera, RGB image with two 5-minute red and green exposures and two 8-minute blue exposures) /// **LOKE TAN**

Top, **THE WHIRLPOOL GALAXY (M51)** (10-inch Meade LX200 SCT at f/6.3, Starlight X-Press MX916 CCD camera, LRGB image of twelve 300-second luminance exposures and five 300-second exposures for the other colors) /// **DOUG SANQUNETTI**

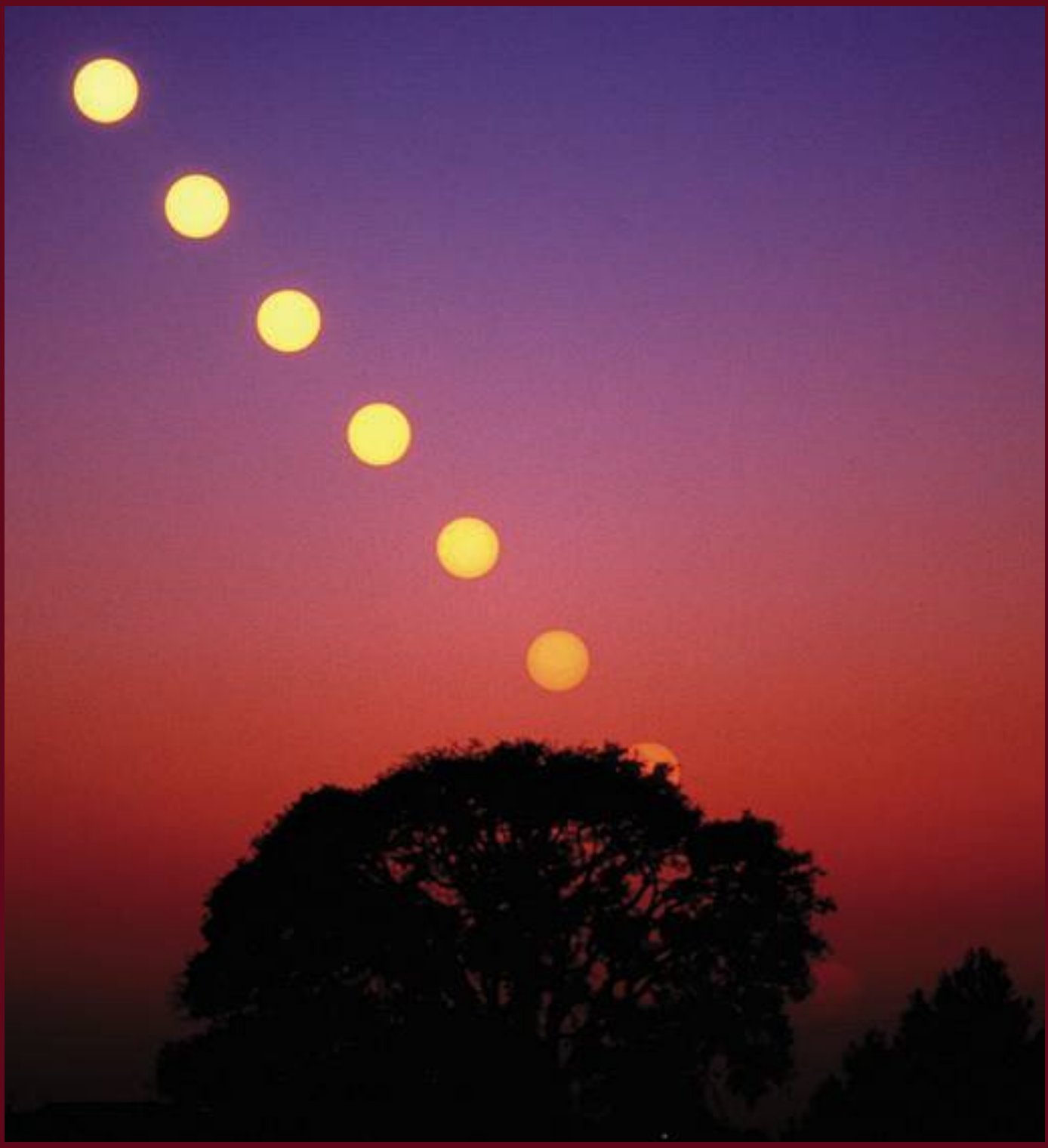
Above, **THE VEIL NEBULA (NGC 6992-5) IN CYGNUS** (4-inch Takahashi FSQ refractor at f/5.3, SBIG ST-10XME CCD camera, hydrogen-alpha/GB image with exposures of 120, 60, and 60 minutes, respectively) /// **DANIEL B. PHILLIPS**

Right, **MOUNT ETNA AND NORTHERN STARS** (Nikon 35mm camera, 35mm lens at f/2, Kodak Ektachrome 100 VS film, 7-minute exposure, taken from Ragusa, Sicily) /// **GIANNI TUMINO AND MELANIA PLUCHINOTTA**

Top, **THE PINWHEEL GALAXY (M33)** (13.4-inch LOMO reflector at f/3.2, Starlight X-Press SXV-H9 CCD camera, 4 Hα/LRGB images with exposures of 360, 360, 600, 600, and 600 seconds, respectively) /// **GERALD RHEMANN AND MICHAEL JAGER**

Above, **SATURN** (11-inch Celestron SCT at f/31, ATK-1HS CCD camera, LRGB image combining 2,900 luminance images and 600 images each of red, green, and blue, taken March 1, 2004, from South Buckinghamshire, England) /// **DAMIAN PEACH**

Right, **NGC 6820 IN VULPECULA** (13.4-inch LOMO reflector at f/3.2, Starlight X-Press SXV-H9 CCD camera, Hα/LRGB image with exposures of 15, 10, 10, 10, and 10 minutes, respectively) /// **GERALD RHEMANN AND MICHAEL JAGER**



SUNSET SEQUENCE (Mamiya 645 medium-format camera, Kodak Ektachrome 100 VS film, landscape exposure taken through an 80mm lens at f/8, $^{1}/_{500}$-second exposure, Sun images every 5 minutes through a 210mm lens at f/8, Baader Astrosolar ND5 filter plus a yellow filter, taken October 12, 1999, from Ragusa, Sicily) /// **GIANNI TUMINO AND MELANIA PLUCHINOTTA**

ORION

STAR PERFORMERS

ShortTube™ 80 EQ Refractor

Compact yet super-capable, it's the ultimate family scope.

$279

StarBlast™ Astro Telescope

Kids will have a blast with this easy explorer.

$169

SpaceProbe™ 130 EQ Reflector

View Saturn's rings, lunar craters, and nebulas galore.

$229

SkyQuest™ IntelliScope™ Dobsonians

XT6	$359
XT8	$479
XT10	$649
XT12	$949

SkyQuest XT6 IntelliScope
Shown with IntelliScope Computerized Object Locater, sold separately.

IntelliScope™ Computerized Object-Locator

Find thousands of celestial objects with pushbutton ease!

$149

Huge selection of scopes and accessories • Friendly, expert service • 30-Day money back guarantee • Fast same-day shipping

FREE *COLOR CATALOG!*
Call toll-free (800)-447-1001 or request it online.

ORION
TELESCOPES & BINOCULARS
telescope.com

OUR 29th YEAR

Everything for the Amateur Astronomer — Delivered Direct

70 • 90 • 105 • 125 ETX AUTOSTAR

The telescopes that have revolutionized amateur astronomy are now available with Autostar® and Field Tripod at very special low prices!

Matchless diffraction-limited optics: *Sky & Telescope* described ETX-90 optics as "excellent…stellar diffraction patterns were virtually textbook-perfect…the Cassini Division in Saturn's rings popped into view despite the rings' low tilt…Epsilon Lyrae's component stars were cleanly split…the Moon was beautiful at any magnification, with black shadows contrasting sharply with illuminated features along the terminator…the mechanics of the optical tube assembly are also first rate."

A long listing of standard-equipment features including rigid fork mounts; dual-axis drive systems with high-torque DC motors on both telescope axes; cordless field operation from eight (user-supplied) AA-batteries that power the telescope for more than 20 hours of normal usage; and internal flip-mirror system for observing or imaging from either the 90° or straight-through positions.

#497 Autostar Controller: The patented Meade Autostar controller brings automatic GO TO operation, plus dozens of additional menu options, to your fingertips, with a database of more than 30,000 celestial objects, including 5,386 galaxies, nebulae and star clusters from the Index Catalog (IC); 7,840 objects from the New General Catalog (NGC); 110 Messier objects; the major planets from Mercury to Pluto; and more.

#884 Deluxe Field Tripod: Constructed of strong, lightweight steel, the full-length Meade #884 Deluxe Field Tripod provides a rigid mounting platform for virtually any ETX observing application. Tripod height is adjustable for seated or standing observing. Use in either equatorial or altazimuth orientations; a graduated scale permits precise polar alignment. For Autostar applications, or for terrestrial observing, the tripod locks to 90°.

Each supplied with #497 Autostar Controller and #884 Deluxe Field Tripod:

ETX-90AT Astro Telescope $595
ETX-105AT Astro Telescope 795
ETX-125AT Astro Telescope 995

Ultra-High Transmission Coatings (UHTC) group increases image brightness by about 20%: ETX-90AT– $50; ETX-105AT– $75; ETX-125AT– $95

Alternately, for the beginning-to-intermediate observer, the ETX-70AT is supplied with #494 Autostar Controller and #882 Field Tripod:

ETX-70AT Astro Telescope 299

Packing & shipping (ETX, Autostar, & Tripod): ETX-90AT — $30; ETX-105AT — $35; ETX-125AT — $40; ETX-70AT — $20.

Meade ETX-125AT
Shown with standard-equipment #497 Autostar Controller and #884 Deluxe Field Tripod.

meade.com

MEADE®
A publicly-traded, employee-owned company (NASDAQ symbol: MEAD)

© 2004